Journal of Construction Engineering, Management & Innovation
2022 5(3):155-167
DOI 10.31462/jcemi.2022.03155167

RESEARCH ARTICLE

The efficiency of photovoltaic panels to meet energy demand of a school building in the Mesopotamia region

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Article History

Received 12 June 2022
Accepted 19 September 2022

Keywords

Building information modeling
Sustainability
Energy analyses
Photovoltaic panels

Abstract

All kinds of energy are one of the basic requirements in life to sustain it. Therefore, the majority of research and applications have been mostly focused on self-sufficient energy or zero-energy buildings in developed countries. Most of these countries encounter energy demand and suffer from carbon dioxide emissions from existing buildings. Energy-efficient applications must be also spread across developing and undeveloped countries especially in the Mesopotamia region due to the hot climate. Hence, the efficiency of a common practice, implementation of photovoltaic panels (PVs), in Iraq is investigated in this study. PVs were designed and empirically implemented in an existing conventional primary school building in Baghdad, Iraq as a case study for the Mesopotamia region. The sustainability and energy analysis of a school building was conducted in diverse scenarios to explore the potential of energy-saving and payback period of the PVs. The slope and number of PV panels located on the school building are the parameters of the current study. Results showed that PV panels with a 30° inclination angle reduced the energy cost of the building by 50%. The payback for the implementation of PVs can be obtained approximately in 8 years. Consequently, the PVs have major potential in energy efficiency and can be implemented in governmental buildings such as public-school buildings in the Mesopotamia region. Besides, society and private institutions may become aware of the importance of sustainable energy with this study. With this case study, the importance of taking advantage of solar energy has been emphasized for undeveloped countries.

1. Introduction

Societies face significant challenges concerning energy consumption, climate change, and energy demand issues. In addition, the surge in energy prices has directed communities to the renewable energy market and led to lower costs of renewable energy technologies benefit as wind, hydropower, solar, biomass, biofuels, geothermal, etc. This situation prompted a major development in energy-saving technologies. One of these developments is the design and/or renovation of existing residential and commercial buildings to achieve energy neutrality and sustainability. A sustainable building can be defined as a building that maintains structural integrity while considering the health,

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safety, and thermal comfort of users, efficiency measures, and environmental impacts.

The development of novel sources and technologies yields creative energy and self-sufficient environments. For instance, Netherland aimed to reach an energy-neutral built environment by 2050. Possible alternatives to reach this purpose were also investigated for low- and mid-rise structures [1] and applied successfully. Some efforts have been paid to find out efficient renovation alternatives for single-family houses or high-rise apartments in Netherland [1-4]. Wells et al. [5] stated that the relatively novel concept in Australia creates substantial opportunities to reduce greenhouse gas emissions, energy demand from fossil fuels, and cost. It is also mentioned that governmental encouragement and acceptance of net-zero energy buildings have a major role to reach an energy-sufficient environment.

Attia et al. [6] showed that there are some factors equally important to the economic challenge that hinder the renovation of existing buildings or designing new ones in line with the net or nearly zero-energy concept in southern European countries. These factors were listed to be technical development, organizational issues, legislation, and enforcement as well as awareness. The Ministry of Urban and Environment of Turkey has also released a guide for the design of nearly zero-energy buildings [7].

Even though there are still some issues that should be solved, underdeveloped or developing countries must adapt themselves to the zero-energy concept to increase their growth speed and reduce energy expenditures. Current energy sources are not infinite and should be replaced with renewable alternatives. Therefore, the main objective of this study is to explore the efficiency of renewable energy technology to reduce energy costs and improve the energy performance of existing buildings in undeveloped countries. For this purpose, an almost 1000-square meters conventional primary school building located in Baghdad, Iraq is considered as a case study in this paper to evaluate and demonstrate the potential efficiency of photovoltaic panels and their payback duration.

2. Background

2.1. Zero energy building (ZEB)

Most of the statistics indicate that the consumption of residential buildings was about 27% to 40% of the total energy resources in the world [8]. To reduce the amount of greenhouse gas emissions, the design of the buildings and the energy source should be chosen to reduce energy consumption. [9]. Additionally, economical savings from the utilized energy by buildings can be employed for the development of undeveloped countries. Hence, reduced energy consumption and clean energy production in these buildings are priceless even for undeveloped countries. Much research has been conducted on self-sufficient or zero-energy buildings (ZEBs) which is a futuristic iteration of green buildings. In general, green buildings are structures designed to enhance resource use such as energy, water, materials, and sustainability [8].

Zero-energy buildings are known as residential or commercial buildings that improve energy efficiency, in addition to making a balance between the energy consumed and the energy generated by the building itself, from renewable sources such as solar or wind energies [10]. These buildings are connected to the regular electrical network as well, where the surplus energy produced can be sold or an additional amount recovered when needed. The basic elements of zero-energy buildings are isolation, window openings, heating and cooling systems, smart energy management systems, and solar cells. Zero energy buildings are also divided into two sub-groups nearly zero energy buildings (Near-ZEB) and net-zero energy buildings (Net-ZEB). The main difference is that Net-ZEB buildings produce and consume exactly equal energy in a certain period whereas Near-ZEB demands additional energy from the electrical network to compensate for its requirement.

Early accreditation plans have been used in western countries including the Building Research Foundation Environmental Assessment

Methodology (BREEAM) in the United Kingdom since 1990 [11], and Leadership in Energy and Environmental Design (LEED) in the United States since 1994 [12]. Other major programs include the Comprehensive Built Environment Efficiency Assessment System (CASBEE) in Japan [13], Deutsche Gesellschaft für nachhaltiges Bauen (DGNB) in Germany [14], and the Green Star System in Australia [15]. The term green building includes energy and water use, indoor environmental quality, material selection method, insulation, and construction site impact as a part of green building definition. From the literature, one of the first accepted interpretations of ZEBs is that proposed by Lund-Andersen et al. [16], which includes some terms such as net-zero site energy, net-zero source energy, net-zero energy costs, and net-zero emissions.

2.2. Photovoltaic panels (PVs)

It is possible to use solar energy to operate electrical appliances by converting energy from the sun to electricity. Where the Mesopotamia region is characterized by a high amount of solar radiation, photovoltaic cells are a direct conversion of solar energy into electricity. PV Systems to harness solar energy can be used in almost all kinds of applications. Exploiting solar energy for domestic use is one of how the energy emitted from the sun is converted into electricity into energy. From the solar energy needed for this, first, the appropriate climatic conditions, and secondly, the delay in the supply of electricity as Middle East countries suffer from large interruptions in electricity, especially in projects for remote areas. Building a photovoltaic system is a process of design, selection, and calculation assessments of equipment used in the system. This process depends on a variety of factors such as geographical location, solar radiation, and load requirements [17].

A Photovoltaic (PV) cell array produces a continuous voltage, which is converted using an inverter to an alternating voltage, to be used later to supply the building with the necessary electrical energy. The produced energy is continuously measured in these systems.

When the array produces an amount of surplus energy, it is sent through the existing electrical network. If the production falls below the required level, the deficiency is compensated by the network. Different types of solar panels are used to serve different needs and purposes depending on the location of the building and the amount of solar radiation that enters the site, as there are single-link solar panels and other multi-link panels that differ among themselves according to the number of layers on the surface. A solar panel monitors sunlight and its direction to get the sunlight smoothly.

Monocrystalline silicon (Mono-SI) solar panel is considered the purest one. It can be easily recognized due to its uniform dark look and rounded edges. The high purity of silicon embedded in this type of solar panel provides higher efficiency rates which reach more than 20%. Monocrystalline panels stimulate high energy output, established in less space. So, the most valuable feature of the Mono-Crystalline Solar Panel is to be slightly less affected by higher temperatures compared to polycrystalline panels [18].

The polycrystalline solar panel (p-SI) can be quickly identified as it is square, has no cut corners, and owns a blue-spotted appearance. Since it is manufactured by smelting raw silicon, it is a faster and cheaper process than that used for monocrystalline panels. This results in a lower final price but also lower efficiency (around 15%), lower space efficiency, and shorter life since they are more affected by higher temperatures. However, the differences between the types of monocrystalline and polycrystalline solar panels are not quite large and the choice will depend strongly on the specific situation. The first option offers a slightly higher space efficiency at a slightly higher price but the power output is essentially the same.

The thin-film solar cell has a lower cost than other solar cells. Thin-film solar panels are manufactured by placing one or more films of photovoltaic materials (e.g., silicon, cadmium, or copper) on a substrate. These types of solar panels are the easiest to produce and the most economical due to the fewer materials needed to manufacture them. It is also flexible since it opens up plenty of opportunities for alternative applications. On the other hand, it is less sensitive to high temperatures. The main problem is that it is established in a huge space, which generally makes it unsuitable for residential installations. In addition, it has a short life cycle because its service life is shorter than monocrystalline solar panels. However, it can be a good option to choose from different types of solar panels if there is a huge space available [19].

Amorphous silicon (a-Si) solar cells are another efficient and widely used solar panel type. They are the cells used primarily in pocket calculators. This type of solar panel uses a 3-layer technology, which is considered the best in the thin film group [20]. The PVs were preferred in the literature intensively to be achieve an almost energy-self-sufficient building. Kasim et al. [21] determined the energy use intensity (EUI) of a dormitory building that uses photovoltaic panels to produce its electricity needs by creating different scenarios. Zaferanchi and Sozer [22] created different improvement scenarios by applying interventions such as lamp replacements, sensors, heat pumps, and the integration of photovoltaic panels. Both of the studies revealed that PVs are highly effective to reduce energy need of the building.

2.3. Research statement

The hot climate is one of the primary weather features of the Mesopotamia region. Thus, there is a high potential to meet energy demand and improve the energy efficiency of the existing buildings in those territories. However, the advantages of energy-efficient solutions have not been adequately considered and practiced so far in this region. The awareness of such potential applications should be provided for practitioners and energy users. It is a well-known fact that most countries in the Mesopotamia regions are either developing or underdeveloped countries. Accordingly, the countries have to consider their energy expenditures and should focus on renewable energy resources to invest in their goods for development. PVs are the most efficient, easy-to-set, and feasible application among alternative renewable energy applications, especially for existing buildings. Thus, the main objective of this study is to explore the effectiveness and reliability of the PVs for existing buildings in undeveloped regions by considering their payback period and clean energy production potential.

This study focused on finding out the best slope for placing solar panels on the roof, the optimum number of panels, and their efficiency according to the coordinates of the site in the summer and winter seasons. Additionally, contribution of other factors, i.e. HVAC System, infiltration, lighting efficiency, etc., to reduce energy demand of the building is analyzed. It can be stated that understanding the clean energy production potential of the PVs in the Mezopotima region will help countries in their development.

3. Research methodology

3.1. Case Study: A Primary school building in Baghdad

A reinforced concrete primary school building located in Baghdad, Iraq has been selected for a case study to prove the efficiency of photovoltaic panels in the Mezopotima region. The thermal properties of the materials used in the building envelope can contribute to the building economy by reducing the energy consumed in the buildings [23]. Monocrystalline solar cells are considered in our research because of their higher efficiency and easy-to-apply characteristics to existing buildings [24].

3.2. Properties of the school buildings

The school consists of three parts an administrative building (one story), classrooms (two-story), and a health group (one story), see Fig. 1.

The administrative building has approximately 250 m^2 which is designed for administrative staff and teachers' rooms and a store. The Health group of the school is near the administrative building. Two-story part of the school is designed for 18 classrooms. This part has almost 600 m^2 of living area.

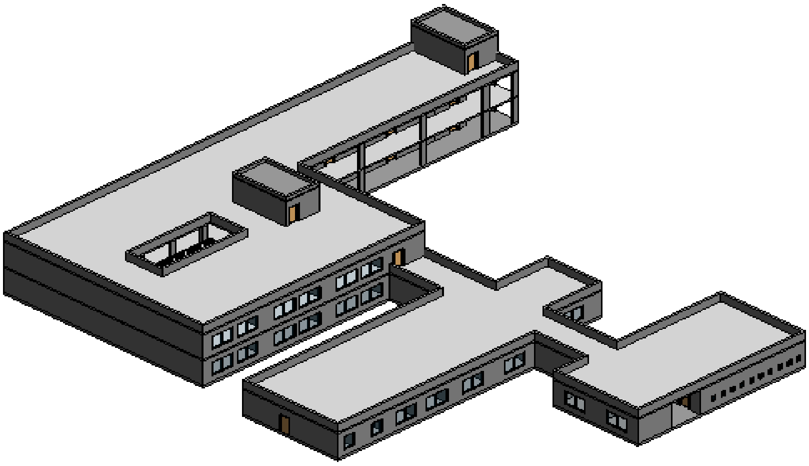

Fig. 1. 3D model of the school building

The walls of the building are of regular bricks, with a thickness of 25 cm The windows in the building are 50 × 150 cm wide, while the bathroom windows are 50 × 100 cm. They are made of aluminum material. As for the heating and cooling systems, they are ceiling fans and electric conditioners.

3.3. Building information model

Building Information Modeling (BIM) is a process that provides creating and managing construction project information throughout the project life cycle. One of the main outputs of this process is preparing the numerical description of each of the original aspects of the building. The digital BIM can be created and maintained as a database that can be easily used and updated [25, 26].

3.4. Numeric model parameters

Insight empowers architects and engineers to design more energy-efficient buildings with advanced simulation engines and building performance analysis data integrated into Revit. It can be accessed through the Revit software in the analysis bar or on the webpage at the Insight 360 website, and it is a tool for comparisons of design options for a building model, by analyzing the sensitivity to the average energy cost by a group of meters. 360 insight dashboard is an interactive work platform that allows the user to compare different Design scenarios without modification to the actual Revit model. Fig.2 shows the model's insight dashboard and, location and climate information.

Analysis results of the default model is considered as a benchmark data to compare with different scenarios. Care must be taken when adjusting the parameter ranges. For instance, it is highly possible to obtain good results according to the index which is not realistic. For example, the lowest cost values can be reached when the ratio of the window is 0%.

The Energy Standard for Buildings Excluding Low-Rise Residential Buildings (1.90 ASHRAE) [27] provides minimum requirements for the energy-efficient design of buildings. Benchmarking is the process of comparing the measured performance of a device, process, or organization with itself, with its counterparts, or with specific standards, to identify and motivate performance improvement when applied in the field of energy use. Performance measurement works like a mechanism to measure the energy performance of a single building over time, for buildings. Also, it can be considered a typical simulation of a reference building based on a certain standard.

Architecture 2030 is asking the global engineering and construction community to adopt the goals of *i)* designing new buildings and restoring old buildings considering fuel and energy efficiency and *ii)* reducing greenhouse gas emissions by 70% compared to the local or regional average for the type of building [28].

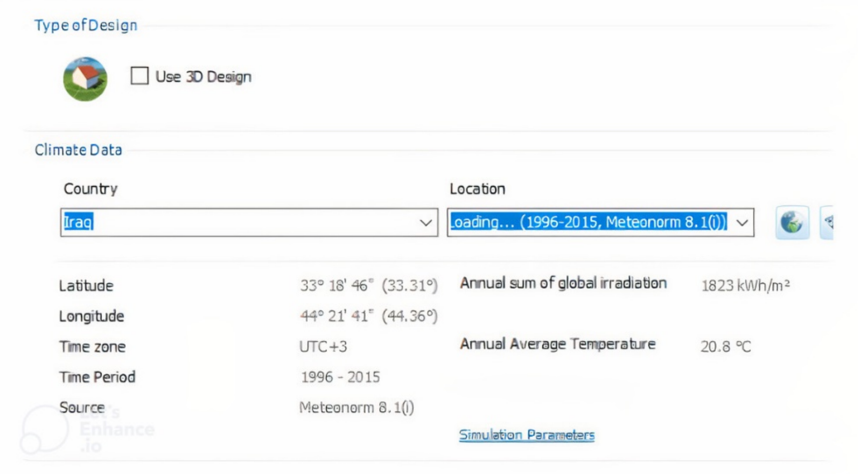

Fig. 2. Annual sun of global irradiation

3.5. PV solar calculations

In this research, we studied a residential building in the Mesepotamia region for its design and energy use. The data is analyzed and validated by Autodesk Insight software for energy analysis purposes [29]. Based on case observations, we analyzed traditional energy consumption with the solar panel system on the roof.

The solar radiation potential of a region can be determined from meteorological data and solar radiation data of national or international energy organizations or solar radiation maps. or, annual solar data are measured with a special pyranometer device and hourly solar radiation power averages are recorded. The solar radiation data was obtained from the PV*SOL tool [30]. This tool has the feature of inputting basic data like location of country and city or load profile and annual energy consumption. The annual radiation value for Baghdad was obtained to be 2069 kWh/m^2, [30].

Determining the surface area covered by photovoltaic panels should be considered the most important factor in the studies to be carried out. In this context, while aiming for the maximum surface area, the interval required for the maintenance and repair of the panels should also be taken into account. So, an efficient placement for the photovoltaic panel system can be achieved as shown in Fig. 3.

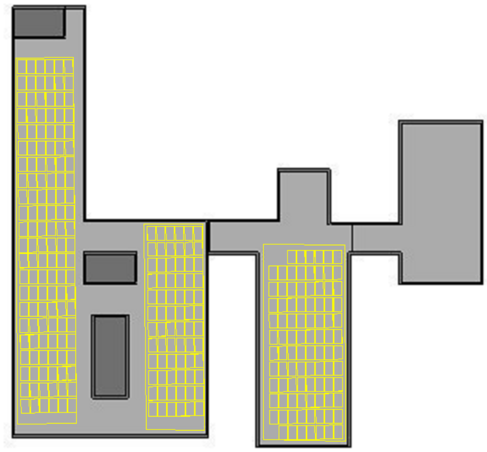

Fig. 3. Module area

The electrical energy produced by the photovoltaic panel and the electrical energy used in the building differs monthly. While the photovoltaic panel can meet the energy needs of the building in the spring and summer months, it was not sufficient to compensate the energy demand of the building during the autumn and winter months. When the electricity production and consumption for a year are examined, as can be seen in Fig. 4, the building started to meet the payback period by producing electricity with the amount of accumulated energy.

The cash balance graph obtained by adding the income from electricity generation to the installation fee spent to calculate the payback period is shared in Fig.5.

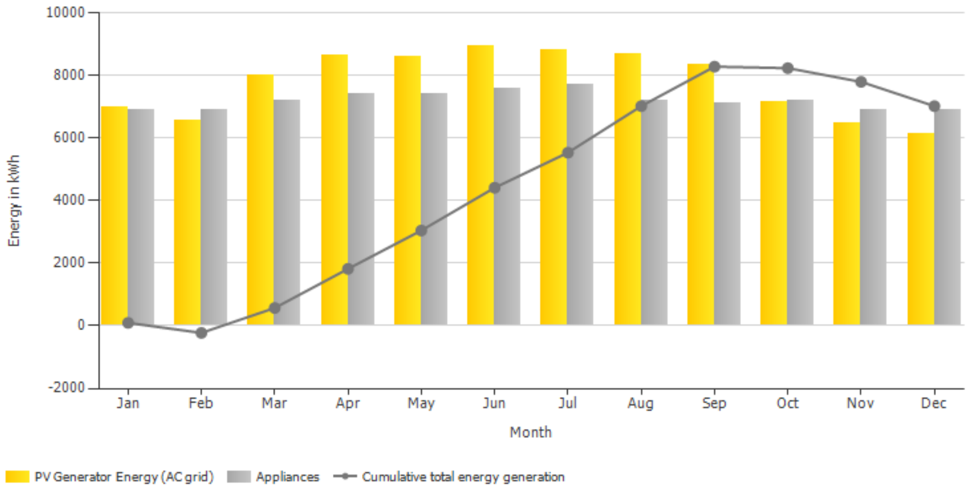

Fig. 4. Production forecast with consumption

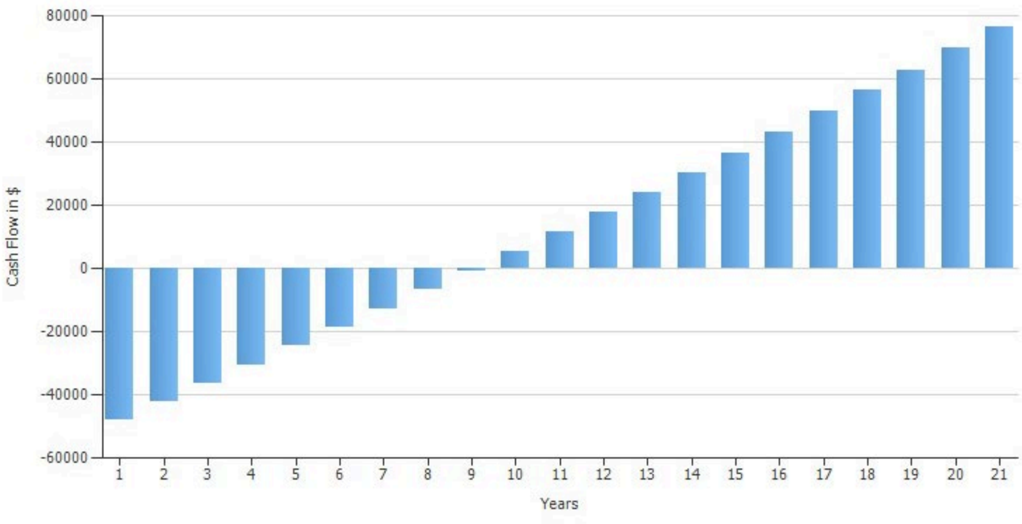

Fig. 5. Cash balance of PV system

It is observed that the payback period of the photovoltaic system is 8 years and 3 months. When the graph obtained with the help of the PV*SOL tool [30] is examined, it is observed that the gained value after 21 years is almost 3 times the cost spent.

To calculate the power and payback period of the photovoltaic panel system, it is first necessary to calculate the energy production value of the photovoltaic panel. In Table 1, the parameters required to calculate the energy consumption of the photovoltaic panel with a numerical calculation process are shared.

While the connected load is the energy consumed by considering all the photovoltaic system elements, the operational demand load shows the consumed load. The Demand Load (DL) is calculated from the connected load value with the help of the Diversity Factor (DF). Considering the calculations in Table 1, the one-day energy production of the PV system is calculated as 240 kWh. In this case, the annual energy production was calculated as approximately 86400 kWh/year.

Table 1. Electricity properties for energy consumption of PV systems

Connected Load(CL)	100 (A)
Diversity Factor(DF)	0.6
Demand Load (DL)	CL×DF=60 (A)
Power Factor(PF)	0.8
Power(P) (V=Voltage, I=Current)	1.732×V×I×PF≅ 30 kW
Energy(E) (t=time, from 8 AM to 4 PM)	P×t = 240 kWh

After calculating the energy consumption of the system, the energy produced by the PV system and the required number of photovoltaic panels will be needed to be calculated. First of all, to calculate the daily radiation amount, the annual radiation amount at the location where the school will be used was determined with the help of the PV*SOL tool [30]. The annual and monthly radiation values to be used to calculate the annual energy need are shared in Fig. 6.

To calculate the energy potential of solar radiation, daily average radiation and panel efficiency values are used. The daily average radiation value is found as 5.67 kWh⁄m^2 per day in Fig. 6. For the photovoltaic panel to be used on the roof, a polycrystal-type photovoltaic panel with an efficiency of 18%, which can be easily found in the market, was preferred. The energy value that a panel can produce in a month is calculated by taking into account the daily average radiation, panel surface area, estimated panel efficiency, and the average monthly number of days [31]. The monthly average energy need is calculated by considering Fig. 4. Detailed calculations are given in Table 2. The optimum angle to be used for the photovoltaic panels used was determined as 30° for Baghdad [32].

As a result of the calculations, it has been determined that 145 panels can meet the monthly electricity consumption. The remaining electrical energy produced by using 220 panels on the roof was sold to the grid system, resulting in income from electricity generation for the existing school. The energy value generated from the PV system by using 220 panels has been 130906 kWh per year. After calculating the energy consumption and production, the investment fee, annual maintenance, and annual income values are taken into account to calculate the payback period of the PV system. The calculated parameters for the payback period are shown in Table 3.

In addition to evaluating success of PVs to produce green energy in undeveloped regions, the parameters causing energy demand is also discussed. The parameters that reduce the energy use intensity of the building are given in Table 4. The effects of these parameters on the total energy consumed ratio are expressed as a percentage.

When Table 1 was examined, it was observed that the highest decrease in energy use intensity value by 29.72% was in the HVAC System selection. Along with the HVAC system, wall construction is the factor that reduces the energy use intensity by 32 kWh per year. The annual impact of wall construction is seen as 10.93%. It is seen that after the HVAC system and wall construction, the most effective factor is roof construction. The effect of reducing the intensity of energy use of roof construction is observed as 12.21 kWh per year, which affects 4.09% of total consumption per year. Lighting efficiency and plug load efficiency, reduce the intensity of energy use, following roof construction with 9.49 and 9.16 kWh per year. Their impact is estimated at 3.18 and 3.07 percent. Those with the least impact on reducing Energy Intensity are infiltration at 4.31 kWh per year at the top of the list. The energy-saving effect is 1.44%. Daylighting and occupancy control were the least effective parameters as the energy intensity reduction effect was 2.84 kWh per year and the operating schedule was 0.34 kWh per year.

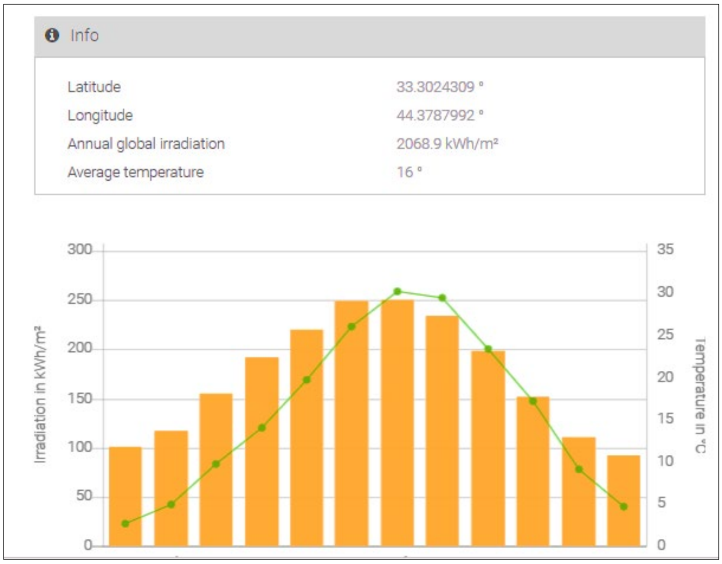

Fig. 6. Annual and monthly average temperatures and global radiation values per square meter for location

Table 2. Calculations and parameters to be used for energy production

Daily Average Radiation	5.67 (kWh/m^2 day)
Panel Efficiency (η_{PV})	%18
Panel Surface Area	1,62 (m^2)
Monthly Energy Produced (for a panel)	49,58 kW/ panel
Monthly Average Energy Need	7200 kWh/m^2 month
Number of panels needed	145
Number of panels used	220
Annually Energy produced (for PV system)	130906 kWh / year

Table 3. Calculations and parameters to be used for cash balance

Installation cost	15000 $
Annual maintenance	150 $
Electricity price for Iraq (Per year)	0,041 kWh/ $
Annual energy production-consumption difference	44506 kWh
Annual income from electricity	1825 $
Payback period	8 year 3 month

Table 4. Insight Scenario for reducing EUI

Number	Scenario	Reduce EUI kWh/m^2 /year (298.11)	Reduce percentage%
1	Building orientation	0	0%
2	Window-to-wall ratio (WWR)	0	0%
3	Windows glass type	0	0%
4	Windows shades	0	0%
5	Wall construction	-32.59	10.93%
6	Roof construction	-12.21	4.09%
7	HVAC System	-88.6	29.72%
9	Infiltration	-4.31	1.44%
10	Lighting Efficiency	-9.49	3.18%
11	Daylighting & Occupancy Controls	-2.84	0.95%
12	Plug Load Efficiency	-9.16	3.07%
13	Operating Schedule	-0.34	0.11%
Total		-159.54	53.49%

Once all the parameters are looked over, it is observed that the amount of Energy Use Intensity reduction per square meter per year is 159.54 kWh in total. The effect of this was considered as constituting 53.49% per annum.

Table 5 shows the extent to which home parameters reduce the dollar price per square meter per year. Using an appropriate HVAC system results in $2.98 per meter square per year saving. Using effective lighting tools reduced the energy cost by $1.29 per square meter per year. The plug load efficiency and wall construction's effect were $1.23 and $1.22 per meter square, respectively. When all the parameters are examined, the total benefit results as $7.81 per square meter per year.

4. Discussion

Through the use of 220 solar panels, it is possible to get enough energy to operate the building. After making the calculations for the cost of the solar energy system and comparing it with the cost of electrical energy used to operate the building, it was concluded that the payback period is eight years and three months.

As the negative effect of renewable energy sources, it can be said that the payback period is quite high since the installation cost is expensive. The use of a solar panel system with a long-term payback period can be turned into a positive one by designing a system that works with its own clean energy.The use of high-speed power plants not only increases the price of electricity but also increases harmful emissions. Power plants with a higher slope rating are significantly more efficient. It is clear from this study that the current system in use allows easy integration with renewable resources. In this research, we dealt with how to use solar panels to reduce energy consumption in existing buildings by calculating the number of panels used and the time required to restore the building's energy. This is especially useful for existing buildings to provide more energy-efficient operation.

Parameters that affect energy consumption in buildings were analyzed with the help of the Autodesk insight interface [29]. While the building consumes 86400 kWh/year of energy annually, it has started to produce 130906 kWh of energy annually with more than necessary solar panels added to the roof. Since the energy production value is more than the consumption value, the building has transformed from the energy-consuming state to the generating state and has remained independent from the grid especially for spring and summer terms.

Table 5. Insight Scenario for reducing cost

Number of scenarios	Scenario Name	Reduce cost $/m^2 /year from the total cost	Reduce percentage%
1	Building orientation	0	0%
2	Window-to-wall ratio (WWR)	0	0%
3	Windows glass type	0	0%
4	Windows shades	0	0%
5	Wall construction	-1.22	6.39%
6	Roof construction	-0.34	1.78%
7	HVAC System	-2.98	15.61%
9	Infiltration	-0.14	0.73%
10	Lighting Efficiency	-1.29	6.67%
11	Daylighting & Occupancy Controls	-0.39	2.04%
12	Plug Load Efficiency	-1.23	6.44%
13	Operating Schedule	-0.22	1.15%
Total		-7.81	40.81%

Different scenarios were examined with the help of Autodesk insight, an interface designed for energy consumption analysis of the building. In these scenarios, parameters such as HVAC system, wall-roof constructions, and lighting system elements were studied. The reducing effect of the relevant parameters on energy consumption was shared. Considering the energy use intensity and cost, it was observed that the HVAC system selection was the most effective parameter.

Similarly, Wijeratne et al. [33] mentioned that PV*SOL tool and Autodesk Revit program are used quite a lot in solar energy analysis in buildings and what kind of results can be obtained. Susnik et al. [34] tested the results by working on two different software, Design Builder and IES VE, to evaluate energy performance. however, it has been observed that BIM energy analysis can have advantages in both cases where it can be evaluated jointly or partially with other programs. Kanters et al. [35] in their study compared the advantages of common programs such as PV*SOL, PVsyst, IES VE, and DesignBuilder, which will be used for solar energy in buildings, according to various stages. PV*SOL outperformed the other programs mentioned at almost every stage. Shin et al [36]. In their study divided a military building into two equal sections and renovated only one section of it as a net energy building. To achieve net-zero performance and reduce the energy demand, several low-energy building technologies were designed and built including a high-efficiency HVAC system, a high-performance building envelope, energy-efficient lighting, and a solar PV system. As a result, it shows that there are 37-50% savings for the renovated part of the building (NZEB) compared to the non-renovated part, depending on the analysis method. Kavitha et al. [37] in their study, compared the glass systems they proposed for the building they designed with the help of Autodesk-Revit (BIM software) and the currently used glass system. In their study, they compared the energy consumption rate in parameters such as HVAC system, electrical system, and misc equipment. It has been observed that the most affecting parameter is the HVAC system(%45-48). Kasim et al. [21] stated that the main feature of the efforts to reduce energy consumption is the selection of air-conditioning systems. Since it is observed that the energy consumption is mostly in the parameter of the HVAC system, it is of great importance to perform energy analyzes in this area. The accuracy of the analyzes can be checked with other programs or numerical calculations, and the studies in this field will increase significantly. This paper considers only a case study in Baghdad for estimating building energy consumption. Since Iraq located on a quite hot region, the consumption rate will be significant when energy consumption in buildings will be used for the cooling system. In addition, since the capacity to benefit from solar energy is high, studies on solar energy-based renewable energy sources will be productive. In this study, it is available to understand the efficiency of such renewable energy systems for existing buildings especially those located in hot climates

5. Conclusion

With the increasing demand for energy and rising energy prices with wars, the importance of energy use is increasing gradually. Therefore, it is of great importance to reduce energy losses by performing energy analyzes in buildings with high energy consumption in undeveloped countries. The studies carried out in this field will expand the use of renewable energy sources and the dependence on conventional energy will be reduced. It will also have an impact on the dissemination and development of the energy performance calculation programs used In this case study, numerical energy demand analyses were performed for an existing school building in Baghdad, Iraq with and without photovoltaic solar panels. In addition to produce green energy through PVs, the parameters that effects the energy demand of the building is evaluated. The building information model was created by using Revit software [38]. Solar radiation analysis were performed by PV*SOL [30]. Following results might be deriven from the study.

- The PVs payback duration is as low as 8.3 years for the evaluated building. Employing PVs converts the building into a energy-free one since its energy production exceeds the consumption. Hence, an additional income is obtained by selling the surplus energy to the grid.

- The PVs can supply an income as much as three times of its investment cost. Hence, the remaining amoun can be utilized for the development of the country.
- Among the parameters which play an important role on the energy demand of the building, HVAC system, wall construction, and lighting efficiency are significant.

Accordingly, this paper may stimulates the awareness of such renewable energy systems to increase the energy efficiency of existing buildings in the undeveloped regions based on the case study results. However, further evaluation at city scale is still required.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

[1] Öztürk SÇ. Net-zero energy renovations of high-rise apartments in The Netherlands. MSc Thesis, Eindhoven University of Technology, Eindhoven, Netherland, 2018.

[2] Costa S. Planning for the future: developing a risk-averse strategy of future-proof zero energy building retrofits for Woonbedrijf considering multiple KPIs and Market. MSc Thesis, Eindhoven University of Technology, Eindhoven, Netherland, 2017.

[3] Plas J. A comparative assessment of ventilative and mechanical cooling for residential zero energy buildings considering the future climate. Eindhoven University of Technology, Eindhoven, Netherland, 2017.

[4] Garufi D. Decision Support Tool for Sustainable Renovation Projects in Dutch Housing Corporations. MSc Thesis, Eindhoven University of Technology, Eindhoven, Netherland, 2015.

[5] Wells L, Rismanchi B, Aye L (2018) A review of net-zero energy buildings with reflections on the Australian context. Energy and Buildings 158: 616-628.

[6] Attia S, Eleftheriou P, Xeni F, et al. (2017) Overview and future challenges of nearly zero energy buildings (nZEB) design in Southern Europe. Energy and Buildings 155:439-458.

[7] T.C. Çevre ve Şehircilik Bakanlığı, Neredeyse sıfır enerjili binalar (nseb) için rehber kitap. 2020, https://webdosya.csb.gov.tr/db/meslekihizmetler/icerikler/nseb_rehber--20201117075919.pdf (in Turkish).

[8] World Green Building Council, Health, Wellbeing & Productivity in Offices, The Next Chapter for Green Building, 2014, Available from: http://www.worldgbc.org/activities/health-wellbeing-productivity-offices/.

[9] Shuvo AK, Sharmin S (2021) Carbon emission scenario of conventional buildings. Journal of Construction Engineering, Management & Innovation 4(3): 134-150.

[10] Wilberforce T, Olabi AG, Sayed ET, Elsaid K, Maghrabie HM, Abdelkareem MA (2021) A review on zero energy buildings–pros and cons. Energy and Built Environment. https://doi.org/10.1016/j.enbenv.2021.06.002.

[11] BREEAM, Building Research Establishment Environmental Assessment Methodology (BREEAM), 2016, Available from: http://www.breeam.com.

[12] USGBC, Leadership in Energy and Environmental Design (LEED) V4, 2016, Available from: http://www.usgbc.org/leed.

[13] CASBEE, Comprehensive Assessment System for Built Environment Efficiency (CASBEE), 2016, Available from: http://www.ibec.or.jp/CASBEE/english/

[14] DGNB, Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB), 2016, Available from http://www.dgnb.de/en.

[15] GBCA, Green Star, GBIG, Green Building Information Gateway, 2016, Available from: http://new.gbca.org.au/green-star/http://www.gbig.org/ places/8194.

[16] Lund-Andersen H, Kjeldsen CS, Hertz L, Brondsted HE (1976) Uptake of glucose analogues by rat brain cortex slices: na+-independent membrane transport. Journal of Neurochemistry 27(2):369–373.

[17] Al-Shamani AN, Othman MY, Mat S, Ruslan MH, Abed AM, Sopian K. Design & sizing of stand-alone solar power systems a house Iraq. The 9th

International Conference on Renewable Energy Sources, 23-25 April 2015, Kuala Lumpur, Malaysia.

[18] Chander S, Purohit A, Nehra A, Nehra SP, Dhaka MS (2015) Influence of temperature on photovoltaic parameters of mono-crystalline silicon solar cell. AIP Conference Proceedings 1661(1):050003.

[19] Hegedus SS, Shafarman WN (20049 Thin-film solar cells: device measurements and analysis. Progress in Photovoltaics: Research and Applications 12(2-3):155-176.

[20] Ge J, Ling ZP, Wong J, Mueller T, Aberle AG (2012) Optimisation of intrinsic a-Si: H passivation layers in crystalline-amorphous silicon heterojunction solar cells. Energy Procedia 1(15):107-117.

[21] Kasim B, Yıldırım G, Köse A, Matur UC, Güllü, A. The energy efficiency of a dormitory building with solar panels: a numerical investigation by using building information modeling. SET 2002-The 19th International Conference on Sustainable Energy Technologies, 16-18 august 2022, Istanbul, Türkiye.

[22] Zaferanchi M, Sozer H (2022) Effectiveness of interventions to convert the energy consumption of an educational building to zero energy. International Journal of Building Pathology and Adaptation. https://doi.org/10.1108/IJBPA-08-2021-0114

[23] Nayır S, Bahadır Ü, Erdoğdu Ş, Toğan, V (2021) The effects of structural lightweight concrete on energy performance and life cycle cost in residential buildings. Periodica Polytechnica Civil Engineering 65(2):500-509.

[24] Bagher AM, Vahid MMA, Mohsen M (2015) Types of solar cells and application. American Journal of Optics and Photonics 3(5):94-113.

[25] Yang D, Estman C (2007) A rule-based subset generation method for product data models. Computer Aided Civil and Infrastructure Engineering 22(2):133-148.

[26] Utkucu D, Sözer H (2020) Interoperability and data exchange within BIM platform to evaluate building energy performance and indoor comfort. Automation in Construction 116:103225.

[27] Edition SI, Erbe DH, Lane MD, Anderson SI, Baselici PA, Hanson S, ...Kurtz RD. Energy standard for buildings except low-rise residential buildings. ASHRAE, Atlanta, GA, USA, Tech. Rep. IP Edition, 2010.

[28] Architecture 2030, Meeting the 2030 Challenge. (2019). Architecture 2030. https://architecture2030.org/2030_challenges/2030-challenge/ (June. 25, 2022).

[29] Autodesk Software Company, Insight 360 Getting Started Guide, 2021

[30] PV*SOL, https://www.pvsyst.com/download-pvsyst/ (August. 15, 2022)

[31] Ceylan M. Electric power plants and electric power transmission and distribution (in Turkish). Seçkin, Ankara, 2016.

[32] Jacobson MZ, Jadhav V (2018) World estimates of PV optimal tilt angles and ratios of sunlight incident upon tilted and tracked PV panels relative to horizontal panels. Solar Energy 169:55-66.

[33] Wijeratne WP, Yang RJ, Too E, Wakefield R (2019) Design and development of distributed solar PV systems: Do the current tools work?. Sustainable Cities and Society 45:553-578.

[34] Sušnik M, Tagliabue LC, Cairoli M (2021) BIM-based energy and acoustic analysis through CVE tools. Energy Reports 7:8228-8237.

[35] Kanters J, Horvat M, Dubois MC (2014) Tools and methods used by architects for solar design. Energy and Buildings 68:721-731.

[36] Shin M, Baltazar JC, Haberl JS, Frazier E, Lynn B (2019) Evaluation of the energy performance of a net zero energy building in a hot and humid climate. Energy and Buildings 204:109531.

[37] Kavitha B, Molykutty MV (20219 Life cycle energy analysis of a glazed commercial building using building information modelling (BIM) tools. Materials Today: Proceedings 37:940-946.

[38] Autodesk, Revit. https://www.autodesk.com.tr/products/revit/ June 25. 2022