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ORIGINAL PAPER

Effectivity of BIM technology in using green energy strategies for construction projects

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Abstract

All over the world, the construction sector is the largest consumer of energy, which has a negative impact on the environment. In this article, the research methodology is adopting building information modeling (BIM) technology in 3D simulation and energy analysis. This study aims using BIM technology to improve indoor daylight performance of the building, determine the proper and comfortable artificial lighting of the building and their costs compared with the traditional methods used to calculate lighting, calculate the amount of renewable energy and cost saving that can be obtained from the photovoltaic panels, assess energy performance analysis at design stage and then create design alternatives to increase energy efficiency. The idea of this research was applied in one of the Iraqi projects; the authors found that applying BIM technology helps a lot in increasing energy performance efficiency through many strategies and it also gives the ability to solve all problems related to the performance of energy in the design stage. The results concluded that applying BIM technology improves indoor daylight performance of the building where the artificial lighting reduce around (29 lamps) as well as the cost of lamps reduce around (6500ID), use photovoltaic(PV) panels reduce annual energy consumption around 44% as well as achieves cost-saving about (22,601 $/year), total electricity consumption equal to (421,645 kw h/year) and total fuel consumption equal to (565,633 MJ/year). Also, the results explain the HVAC system is the most effective alternative where annual energy saving is around (50%).

Keywords BIM · GBS · Green energy strategies · Create design alternatives · Daylight analysis · PV panel analysis

Introduction

Buildings worldwide were responsible for approximately 32% of energy consumption and the emission of 19% of energy-related greenhouse gases in 2010 (Abanda and Byers 2016). These estimates negatively affect the environment and societies through global warming. With the growing threats of global warming, it is not surprising that the construction industry now begins to meet the need for energy-efficient buildings (Bynum et al. 2013). In Iraq, the electricity crisis causes air pollution and poor quality, which greatly affects the health and safety of Iraqi citizens (Chaichan 2016). The traditional CAD planning method does not support the possibility of early decisions; energy and performance analysis is generally performed after preparing architectural and construction design documents (Azhar et al. 2009). Building information modeling (BIM) is an innovative approach that includes many tools that can effectively assess energy performance in the building (Najjar et al. 2017). BIM technology has the ability to model virtual environments similar to the real work environment and thus solve all problems at the early stage of the project (Abed et al. 2020; Abed et al. 2019a, b). The use of computer technology can contribute greatly in facilitating and improving work (Hatem et al. 2012). BIM is a unified and comprehensive system for everything related to the construction project (Hatem et al. 2018). A new approach, called building energy modeling (BEM), is based on building information modeling (BIM) (Gao et al. 2019). The design team can take advantage of BEM when applied at the design stage where design alternatives can be found in terms of energy consumption and

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thermal comfort and can also be compared between alternatives (Maile et al. 2007).

The construction sector in Iraq is considered to be the most energy-consuming and affecting sector on the environment; this is due to the lack of an assessment of the building's energy performance in the early design stage, as well as the lack of awareness among designers and architects about the importance of assessing energy performance during the design phase, as well as designers and architects depending on the CAD method in their calculations and designs, which is an ineffective way to assess the energy performance. In fact, this led to an increase in the rate of energy consumption and pollution in recent years. In this study, the authors seek to achieve the following goals:

1. Improving indoor daylight performance of the building by adopting BIM technology.
2. The role of BIM technology in determining the proper and comfortable artificial lighting of the building and their costs compared with the traditional methods used to calculate lighting.
3. Using the BIM technology to calculate the amount of renewable energy and cost saving that can be obtained from the photovoltaic panels.
4. Using BIM technology to assess and energy performance analysis at design stage.
5. Adopting BIM technology in creating design alternatives to increase energy efficiency.

Paper structure

After Introduction, the paper structure is organized as follows: Section two explains the literature review and methodology framework of this study as well as illustrates the selected case study (Deanship Building of Agriculture Collage). Section three discusses the results of this study obtained by applying BIM technology to improve energy efficiency through daylight analysis, photovoltaic (PV) panels analysis, energy analysis, and create design alternatives. Section four explains the conclusions and limitations of this study.

Literature review

Several researchers have focused on improving energy efficiency in the building. For example, Azhar and Brown (2009) investigated the feasibility of using BIM in sustainability analysis. Che et al. (2010) studied the possibility of using BIM to improve energy efficiency, use of Revit as a measure of energy and visualize the performance standards. Park et al. (2012) found that the energy assessment problem can be solved using data-based BIM technology. Abanda and Byers (2016) studied the effect of orientation on energy consumption in construction and evaluated how BIM may be used to facilitate this process. Najjar et al. (2019) suggested a framework that depended on various performance criteria to enable decision-makers to use standard procedures and software for sustainable energy use and management in the building. Naji et al. (2019) investigated the reasons for the displeasure of the Iraqi citizens with the privatization of electricity due to a large increase in electricity bills as well as use different alternatives to reduce electrical energy consumption. Singh and Sadhu (2019) proposed developing new strategies to identify critical variables that contribute to energy efficiency and design more efficient housing. Kaveh and Vazirinia (2019) found the appropriate schedule for appliance by creating a trade-off between design standards by incorporating multi-criteria decision-making (MCDM) techniques and multi-objective optimization (EMOO) techniques.

Research methodology and experimental work

In this part, the authors will clarify the research methodology for this study and, in addition, explain the case study.

Research methodology

In this study, the authors will depend on the tools provided by BIM technology through simulation and energy analysis at the design stage to find the best strategies to increase the efficiency of energy performance in the construction sector. Figure 1 illustrates the research methodology selected to achieve the goals of this study. This research methodology is organized as follows:

1. Select the case study and collect data related to the construction project (2D drawing, priced schedule quantities).
2. Create 3D model of case study:
   - Revit 2018 was used to model the case study as shown in Fig. 2.
   - Revit2018 is easy to use compared to other modeling software.
3. Use Autodesk insight 360 plug-in added to Rivet 2018 for:
   - Daylight analysis
     Daylight analysis is performed by using a lighting tool that is added to Revit 2018 which increases daylight performance and energy efficiency.
   - Photovoltaic (PV) panel analysis

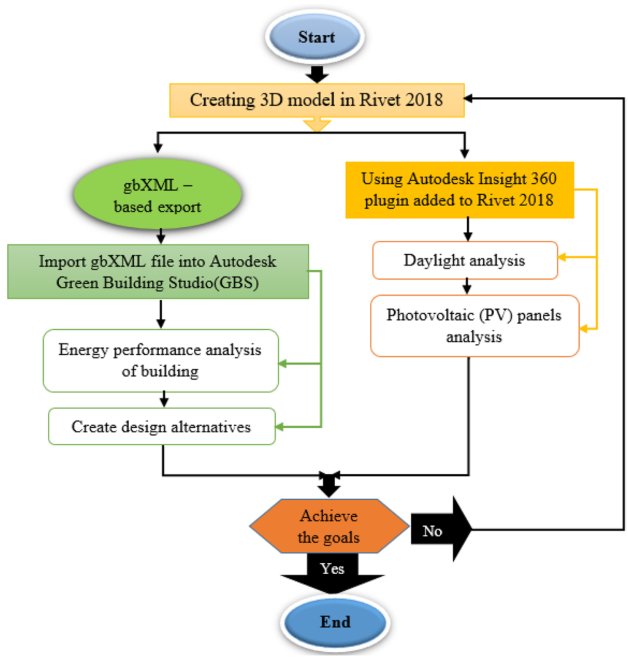

Fig. 1 Research methodology

PV panel analysis is performed using a solar tool that is added to Revit 2018 which contributes to increased energy efficiency.

4. Export gbXML file to Autodesk Green Building Studio (GBS) for:

- Energy performance analysis of building
  Autodesk GBS cloud service is very useful to analyze the environmental impacts of building components during the design stage where we can perform energy analysis, cost analysis, water efficiency analysis, etc. Figure 3 shows the necessary input information to GBS before importing gbXML file.
- Create design alternatives
  GBS helps in creating different alternatives and finding the amount of their impact on energy consumption such as the building orientation, WWR ratio, glass type, roof type, walls type, HVAC system and lighting control type.

5. Check if the result achieves the goals or no.

Experimental work: case study

This project is one of the main educational projects at Diyala University. This building consists of two floors with total area 2924 m^2. The project was referred by Diyala University to a local company in 2010 with an estimated cost of (1693,308,500 ID, note that 1$ = 1191ID). The project was stopped in 2011, in 2013 acceleration committee was formed from engineers at Diyala University to complete the remaining work, and project was completed in 2018; other details of the building are summarized below:

- Project name (Deanship Building of Agriculture Collage).
- Type of contract (unit price contract).
- Lighting type (fluorescent lamp).
- Ground floor (begins from level 02 and end of level 03 and contains 36 rooms, ground floor height 3.65 m).
- First floor (begins from level 04 and end of level 05 and contains 46 rooms, first floor height 3.65 m).
- The material used in the case study and other components are shown in Table 1.

Results and discussion

The results were conducted and discussed according to the following stages:

Daylight analysis

The lighting tool added to the Revit 2018 allows daylight analysis to know the amount of daylight that can be obtained from sunlight; daylight analysis depends mainly on the orientation of the building

Most of the daylight was focused in the area of curtain wall, and most of the rooms that were in the southeastern

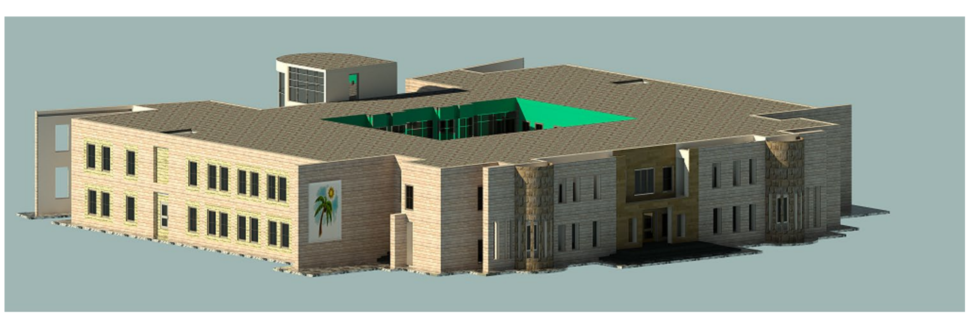

Fig. 2 3D BIM model of case study

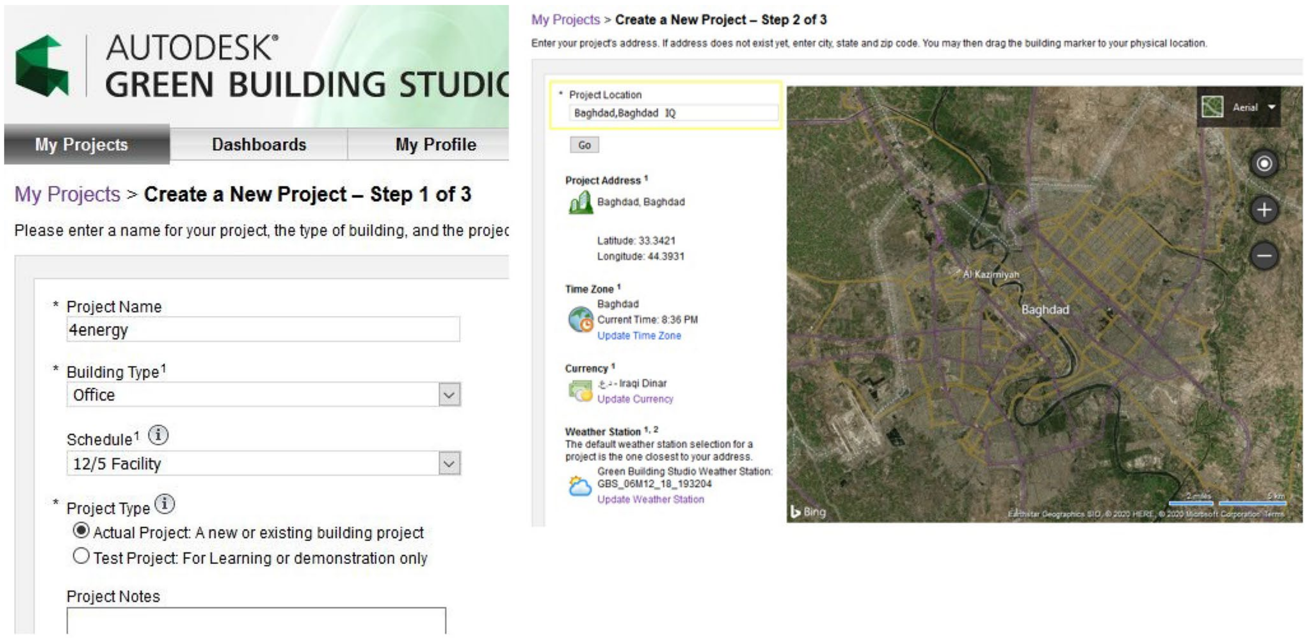

Fig. 3 Information input required in GBS

Table 1 Material and components of case study

Building element	Material/components	Thickness (m)	Thermal conductivity (W/m k)
Exterior walls 1	Brick	0.23	0.12
	Gypsum	0.02	0.42
	Cement mortar	0.02	0.72
	Stone (Sino)	0.1	1.22
Exterior walls 2	Brick	0.23	0.12
	Oil paint	0.01	0.51
	Cement plaster	0.02	0.72
	Gypsum	0.02	0.42
Interior walls 1	Brick	0.23	0.12
	Gypsum	0.02	0.42
Interior walls 2	Brick	0.11	0.12
	Ceramic tiles	0.02	1.2
Roof	Concrete	0.2	1.0461
	Asphalt	0.03	1.15
	Soil	0.15	0.837
	Concrete tiles	0.04	1.0461
Floors	Concrete	0.2	1.0461
	Marble	0.02	2.9
Curtain walls	Double glass	NA	1.1
Windows	Double glass	NA	1.1

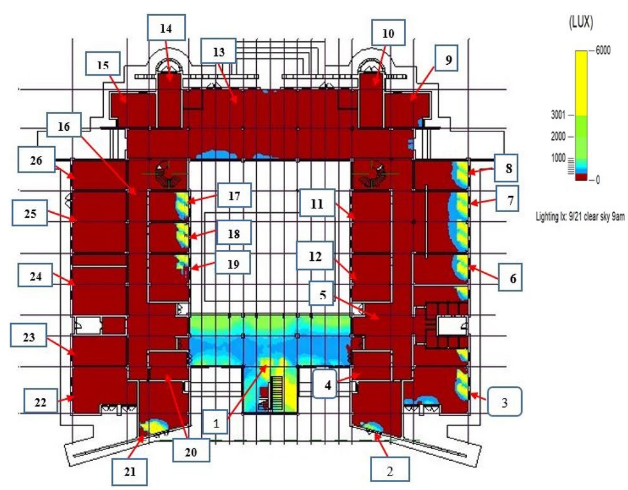

Fig. 4 Daylight analysis of ground floor at 9:00 a.m

side got a percentage of the daylight while the rooms in the northwestern side did not reach any daylight as shown in Figs. 4 and 5. By using daylight analysis, there is a high possibility to improve indoor daylight performance of the building, modifying the area of the window or including shading strategies for the areas with high daylight.

The authors calculated the total illumination, number and cost of lamps for the basic rooms on the ground floor in consultation with expert electrical engineers; according to (Hickey 2004), lighting calculations are performed according to steps as shown in Table 2.

Table 3 illustrates the effect of the daylight ratio obtained from daylight analysis in Revit 2018 on the ratio of total illumination required for each room, which effects on the number and cost of the required artificial lamps. The number

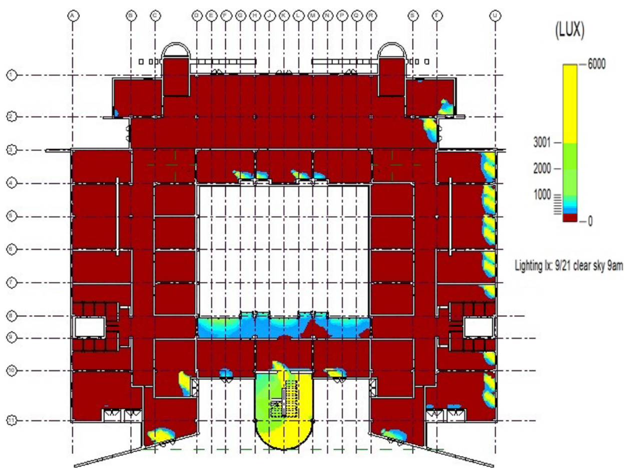

Fig. 5 Daylight analysis of the first floor at 9:00 a.m

of required artificial lamps reduced around (29 lamps) which leads to reduced energy consumption and the cost artificial lamps reduced around (65000ID).

F = total illumination for each room
F_1 = natural illumination (F_{total}*daylight ratio)
F_2 = new total illumination for each room without natural illumination ($F_{total} - F_1$)

Photovoltaic (PV) panel analysis

Photovoltaic (PV) panels are one of the most important sources of renewable energy generation in the world. PV panels convert solar energy into electrical energy that can be used for cooling, lighting, heating and other purposes. Solar tool added to Revit 2018 allows for PV panel analysis. This analysis needs to enter some information to perform the analysis correctly such as the location, building area, energy use intensity, electricity cost per kilowatt-hour and the efficiency of the solar panels and coverage from the total surface area and payback filter to payback limit.

Figure 6 shows the result of PV panel analysis; the PV panels are very useful in this study where energy production is 251,126 kW h/year which reduces energy consumption about 44%, achieves cost saving around 22,601 $/year and payback limit around 29 years.

Energy analysis

Figure 7 illustrates the result of energy analysis in GBS; the result shows the annual carbon emission from fuel equal to 28.2 Mg, energy use intensity equal to 712 MJ/m^2/year which included energy consumption by electricity and fuel sources, total electricity consumption equal to 421,645 kW h/year and total fuel consumption equal to 565,633 MJ/year.

Figure 8 shows the most energy consumption for cooling purpose because weather is hot for most months of Iraq.

Table 4 shows large variations in monthly energy consumption during the year, which fluctuated between 27,930 kW h in March where most consumption in this month is around 28% for purposes of equipment, and 69203 kW h in December where most consumption in this month is around 77% for purposes space heat.

Create design alternatives

Table 5 shows alternatives which are selected in consultation with expert designers were created and evaluated in GBS; the result shows the energy saving and carbon emission of alternatives where annual energy saving is equal to 535710 kW h/year and HVAC system has a high impact on energy consumption and carbon emission and the type of wall has a high effect on energy consumption and carbon emission.

Annual energy saving kW h/year = annual energy consumption of building –annual energy consumption of alternative.

Figure 9 illustrate annual energy saving percent of proposal alternatives are:

1. Orientation around (0.50%).
2. Window to Wall Ratio (WWR) around (0.20%).
3. Windows Shaded around (1.2%).
4. HVAC System around (50%).
5. Lighting Controls around (1.56%).
6. Windows Glass type around (4.10%).
7. Wall type around (33%).
8. Roof around (1.38%).

Annual energy saving % = (annual energy of building- annual energy of alternative)/(annual energy of building)*100%.

Table 2 Steps for calculating artificial lighting

Step 1	Step 2	Step 3
$Cr = 5*h*(L+W)/L*W$ Cr = cavity ratio H = height of the cavity (h−0.75) L = length of the room W = width of the room	$F = E*A/Y*P$ F = total illumination for each room E = degree of illumination A = area of room Y = utilization factor P = maintenance factor	No. of lamps = total illumination (lux)/illumination of lamp (lux)

Table 3 Effect of daylight ratio on number and cost of lamps for ground floor

Rooms (no.)	F_{Total} (lux)	No. of lamps	Cost of lamps (ID)	Daylight ratio	F_1 (lux)	F_2 (lux)	New no. of lamps	New cost of lamps (ID)
Door way 1 (1)	45,134	8	40,000	88%	39,717	5416	1	5000
Cafeteria (2)	28,768	5	25,000	6%	1726	26,467	4	20,000
Rest room (3)	5041	1	5000	16%	807	4234	1	5000
Service room (4)	16,219	3	15,000	0	16,219	16,219	3	20,000
Corridor 1 (5)	30,536	5	25,000	0	30,536	30,536	5	25,000
Manger room (6)	24,036	4	20,000	12%	2884	21,151	3	15,000
Associate manager room (7)	29,506	5	25,000	15%	4426	25,080	4	20,000
Secretary ship room 1 (8)	23,404	4	20,000	21%	4915	18,489	3	15,000
Maintenance room 1 (9)	21,145	4	20,000	0	21,145	21,145	4	20,000
Maintenance room 2 (10)	19,462	3	15,000	0	19,462	19,462	3	15,000
Promotions committee room 1 (11)	28,399	5	25,000	0	28,399	28,399	5	25,000
Promotions committee room 2 (12)	22,129	4	20,000	0	22,129	22,129	4	20,000
Door way 2 (13)	45,492	8	40,000	2%	910	44,582	8	40,000
Guardroom (14)	9731	2	10,000	0	9731	9731	2	10,000
Library room (15)	21,144	4	20,000	0	21,144	21,144	4	20,000
Corridor 2 (16)	36,145	6	30,000	0	36,145	36,145	6	30,000
Manger room (17)	17,146	3	15,000	12%	2058	15,088	2	10,000
Secret pen room (18)	18,536	3	15,000	11%	2039	16,497	2	10,000
College council room (19)	22,129	4	20,000	9%	1992	20,137	3	15,000
Recording room 1 (20)	16,219	3	15,000	0	16,219	16,219	3	15,000
Recording room 2 (21)	24,304	4	20,000	7%	1702	22,602	4	20,000
Registration manager room (22)	30,243	5	25,000	0	30,243	30,243	5	25,000
Recording room 3 (23)	24,036	4	20,000	0	24,036	24,036	4	20,000
Meeting room (24)	26,174	5	25,000	0	26,174	26,174	5	25,000
Dean's room (25)	34,898	6	30,000	1%	349	34,549	6	30,000
Secretary ship room 2 (26)	23,405	4	20,000	0	23,405	23,405	4	20,000
Total		122	560000ID				93	495000ID

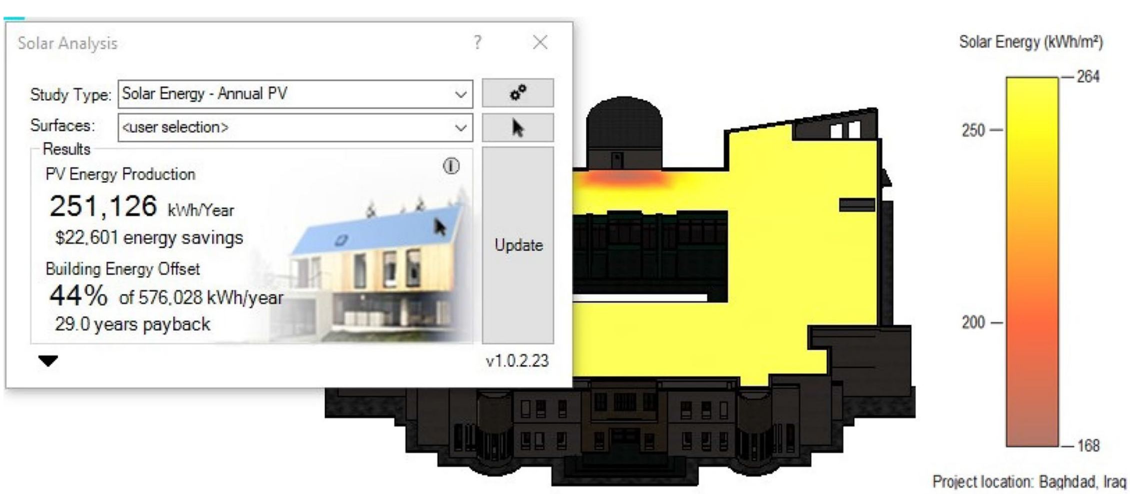

Fig. 6 Result of PV panel analysis

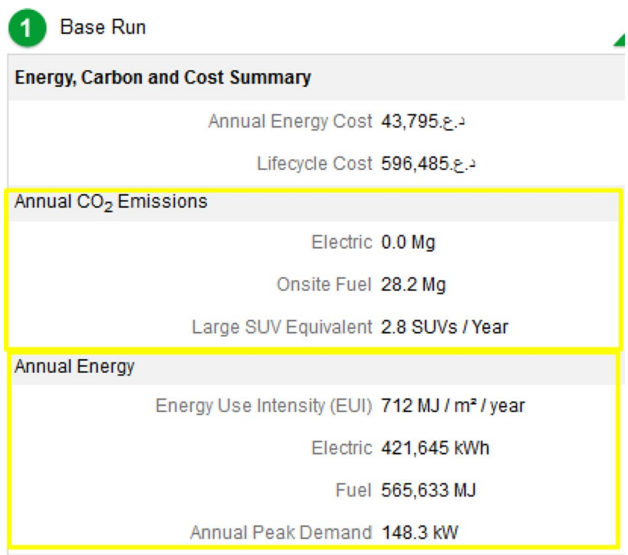

Fig. 7 Energy analysis result in GBS

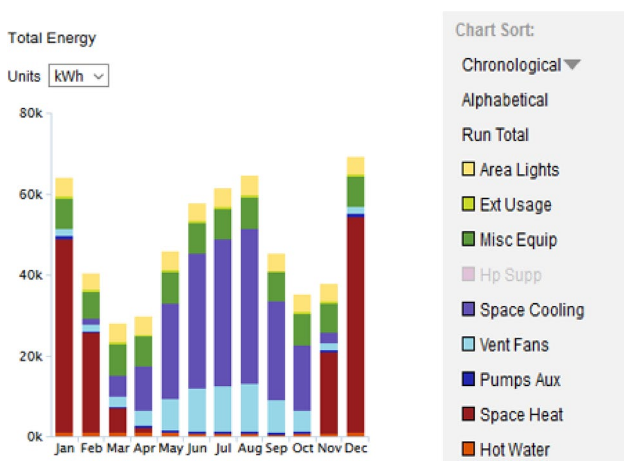

Fig. 8 Monthly energy consumption

Conclusions

The buildings contributed a lot to the large consumption of energy, which leads to the depletion of resources as well as the negative impact on the environment. Thus, as a result of these reasons, authors are trying to find the necessary solutions to preserve the environment and improve these buildings by adopting modern computer technologies, including BIM technology. Depending on the result, authors conclude the following:

1. Daylight analysis contributed to identify the location and ratio of daylight which entered the building during the day, helping designers and architects to improve the internal daylight performance in the building.
2. Daylight ratio obtained from daylight analysis contributed to reduce the number of lamps and thus reduce the energy consumed as well as reduce the cost of lamps.
3. Photovoltaic (PV) panel analysis contributed to the knowledge that the use of the photovoltaic panels has a major role in reducing energy consumption and thus reducing the effect of building energy on the environment.
4. The use of Autodesk Green Building Studio in energy analysis gives accurate details, helping designers and architects understand and evaluate the building's energy performance in the early design stages.
5. Autodesk Green Building Studio is an effective tool in designing and evaluating the effect of different alternatives on energy consumption and carbon emission, as it provides designers and architects the opportunity to find the best alternatives that increase energy efficiency at the early design stage.

Table 4 Large variations in monthly energy consumption

Month run total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dc
Total monthly energy (kW h)	63,954	40,435	**27,930**	29,681	45,782	57,625	61,284	64,490	45,261	35,376	42,720	**69,203**
Area light %	7%	10%	16%	15%	10%	8%	7%	7%	9%	13%	11%	6%
Misc. Equip %	12%	17%	**28%**	25%	17%	13%	12%	12%	16%	22%	19%	11%
Space cooling %	0	3%	19%	36%	52%	58%	59%	59%	54%	45%	7%	0
Ext usage %	1%	1%	2%	2%	1%	1%	1%	1%	1%	2%	1%	1%
Vent fans %	3%	4%	9%	13%	17%	18%	18%	18%	17%	15%	5%	3%
Pump aux %	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Space heat %	75%	61%	21%	4%	0	0	0	0	0	0	53%	**77%**
Hot water %	1	3%	4%	4%	2%	1%	1%	1%	1%	2%	3%	1%

The values of the highest energy consumption and the lowest energy monthly consumption, as well as the high and lower percentage of energy consumption, were identified as significant values and they are in bold

Table 5 Energy saving and carbon emission of alternatives of case study

Alternative type	Alternative name	Energy consumption of alternatives (kW h/year)	Energy saving (kW h/year)	Carbon emission (Mg/year)
Orientation	315	575,623	3143	28.4
WWR	15%	577,244	1522	28.3
Shaded	2/3 win height	572,262	6504	29.4
HVAC system	Package terminal heat pump (PTHP)	289,915	288,851	1.8
Lighting control	Occupancy and daylight control	569,692	9074	28.6
Glass type	Green glass low-e	554,799	24,967	22.9
Wall type	Insulated concrete form 14in. thickness	385,109	193,657	11.9
Roof	Wood frame R60	570,774	7992	27.2
Total energy saving	535710 kW h/year			

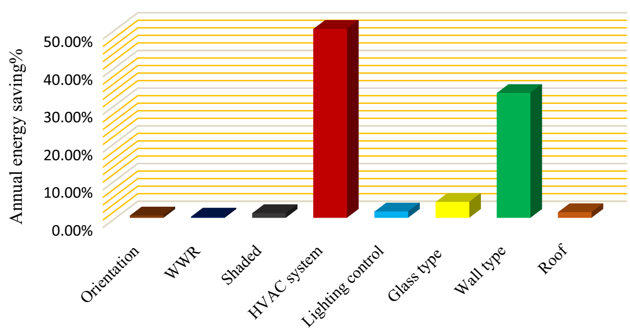

Fig. 9 Annual energy saving percent of alternatives

Limitations

The limitations of this study are applying green energy strategies in the design stage of the project. Future studies should apply green energy strategies in the study of green buildings using recycled materials and their impact on the environment.

Compliance with ethical standards

Conflict of interest There is no conflict of interest.

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