Global J. Environ. Sci. Manage. 6(4): 467-480, Autumn 2020

Global Journal of Environmental Science and Management
(GJESM)

Homepage: https://www.gjesm.net/

ORIGINAL RESEARCH PAPER

Effective energy consumption parameters in residential buildings using Building Information Modeling

N. Amani[*]**, A.A. Reza Soroush**

Department of Civil Engineering, Chalous Branch, Islamic Azad University, Chalous, Iran

ARTICLE INFO

Article History:
Received 08 January 2019
Revised 15 March 2020
Accepted 30 April 2020

Keywords:
Building energy conservation
Building Information Modeling (BIM)
Energy efficiency
Energy management
Energy simulation

ABSTRACT

Building information modeling can help in predicting the energy efficiency in future based on dynamic patterns obtained by visualization of data. The aim of this study was to investigate the effective parameters of energy consumption using BIM technology which can evaluate the buildings energy performance. First, three forms of general states in the building were modeled to evaluate the proposed designs in Autodesk Revit Software. Then, the main building form for energy modeling and analysis was selected. Autodesk Revit 2020 software was also used to obtain the results of climate data analysis and building energy consumption index. Finally, the most optimal mode was selected by examining different energy consumption modes. The results showed that the use of building information modeling technology in adjusting the parameters affecting energy consumption can save energy cost up to 58.23% in block D. Energy cost savings for block C and the western lobby were obtained as 51.03% and 43.05%, respectively. Based on energy use intensity, energy cost savings for blocks C, D, and the western lobby were estimated as 16.67%, 16.30%, and 11%, respectively. The results of parametric studies on alternative schemes of energy use intensity optimization showed that 16.30% savings could be achieved by the base building model in a 30-year time horizon. Therefore, it was concluded that optimization of energy consumption would reduce the environmental pollutants emission and contribute to preservation and sustainability of the environment.

DOI: 10.22034/gjesm.2020.04.04

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
27	6	10

*Corresponding Author:
Email: *nimaamani@iauc.ac.ir*
Phone: +98011 447749800
Fax: +98 11-4474-7833

Note: Discussion period for this manuscript open until January 1, 2021 on GJESM website at the "Show Article.

INTRODUCTION

Along with rapid increase of energy consumption the concerns about production problems, degradation of energy resources and severe environmental impacts (loss of ozone layer, global warming, climate change, etc.) have been increased in the world (Jung *et al.*, 2013). Nowadays, energy efficiency in the building is the main objective in energy policy at regional, national, and international levels (Pérez-Lombard *et al.*, 2008). Achieving sustainable development at the national level requires minimizing the impact of building on the environment by reducing energy consumption (Choi *et al.*, 2016). The current methods and techniques for energy simulation of buildings are time-consuming and difficult. Moreover, they suffer from lack of high interaction capability between the theoretical and real energy data.)Venkataraman and Kannan, 2013). Early phases of building design play a crucial role in the performance of a building's life cycle in terms of resources, energy consumption and life cycle costs (Kovacic and Zoller, 2015). Analyzing the energy performance of a building during the early design stage requires access to specific information such as properties of materials, U-value, and technical systems. Such information is one of the determinants of building energy performance (Schlueter and Thesseling, 2009). Insufficient adaptation due to the complexity of data exchange between architectural design and building energy simulation prevents the effective use of energy performance analyses in the initial design stage (Kim *et al.*, 2015). Efficiency of energy resources in new buildings can affect the design of a building by adopting an integrated approach (Venkataraman and Kannan, 2013). Building information modeling (BIM) is a good candidate to be used for extracting the data such as daylighting or energy in different areas. (Cemesova *et al.*, 2015). BIM consists of digital representation of physical and functional characteristics of a building. It is used as a common source of information about a building's reliable facilities for decision making during its lifecycle from the beginning to the end (Shivsharan *et al.*, 2017). Based on literature review, the main potentials and value-added for accepting BIM technology in the energy sector have been summarized in Table 1. Famous database (sciencedirect, emerald, ASCE, tandfonline) has been searched using the keywords including energy conservation, BIM, effective parameters, and cost saving. All the authors whose fields of study were close to the theme of this study were extracted. The findings show that no studies have addressed the effective parameters of building energy using BIM.

Today, most of the environmental problems in the world are related to the use of fossil fuels, especially in the construction sector. In Iran, a considerable amount of energy is annually consumed in the building and housing sectors. The share of buildings' fuel consumption in 2016 was about 41.4% of the total energy consumption in the country, which was the highest amount of energy consumption (Ministry of Energy, 2016). Due to the large share of final energy consumption in this sector, accurate analysis of the thermal and cooling loads of a building and efforts to reduce energy losses in it are effective ways to reduce energy consumption. Energy performance assessment using BIM would save a lot of time and money (Choi *et al.*, 2016). This study attempts to render energy performance assessment based on Building Information Modeling technology (BIM-EPAs) and indicates that it can help in design identification, comparison, and reduction of energy consumption in the initial phase of design. The aim of this study is to investigate the effective parameters envolved in energy consumption and uses Building Information Modeling (BIM) technology to evaluate the buildings energy performance. This study has been carried out in Bandar Anzali, Iran during 2019-2020.

MATERIALS AND METHODS

Software selection

Autodesk Revit 2020 was selected to create a building information model. One of the reasons for choosing this software as a reference software is its tools for different design strategies with a modeling approach from bottom to top and top to bottom. Using the Autodesk internal plugin of the site, it is also possible to perform energy analysis in this software. Another application of this software is support of building data output in standard formats (such as IFC and gbXML), which makes it possible to perform energy analysis by other energy analyzer software. To perform energy analysis in this study, an energy-related tool was used. This tool was chosen due to its good ability to create an energy model and visualize it in early design studies. Moreover, Autodesk Green Building Studio (GBS) software is used to obtain the results of climate data analysis and building energy

Table 1: Previous studies on main potentials and value-added for accepting BIM technology in the energy sector

Author(s)	Title	Potentials of BIM	Value-added	Y
Singh and Sadhu	Multicomponent Energy Assessment of Buildings using BIM	Building performance analysis	Improving design quality and energy efficiency	2019
Farzaneh *et al.*	Review of using BIM for building energy modeling	Integrated design and building performance analysis	Improving design quality and energy efficiency	2019
Gao *et al.*	Building information modeling-based building energy modeling	Integrated design and energy analysis	Improving design quality and energy efficiency	2019
Najjar *et al.*	Integrated energy optimization and life cycle assessment with building information modeling	Help to perform buildings performance analysis	Reducing energy consumption and resources	2019
Nizam *et al.*	A BIM-based tool for assessing embodied energy for buildings	Integrated design and building performance analysis	Improving design quality and reduced the environmental impacts of the building	2018
Banteli and Stevenson	Analysis of energy and carbon in early-stage design using BIM	Help to perform buildings performance analysis in early-stage design	Energy efficiency and reduction of greenhouse gas emissions	2017
Beazley *et al.*	Enhancing energy efficiency in residential buildings using BIM	Integrated design and energy analysis	Increasing energy efficiency	2017
Egwunatum *et al.*	Assessment of energy consumption and leakage in buildings with building information model energy	Integrated design and energy analysis	Improving design quality and energy efficiency	2017
Gerrish *et al.*	BIM application to building energy performance visualization and management	Visualization and management of building performance	Improving interoperability and building performance management	2017
Habibi	BIM for improving building performance	Integrated design and energy analysis	Improving design quality and energy efficiency	2017
Maltese *et al.*	Sustainability assessment through green BIM	Using BIM in the building lifecycle	Improving design quality	2017
Abanda and Byers	An investigation of the impact of building orientation on energy consumption using BIM	Building performance analysis	Reducing energy consumption	2016
Guo and Wei	Evaluation of cost-effective energy saving	Integrated design and economic analysis	Improving design quality and cost efficiency	2016
Kurian *et al.*	Sustainable Building Design based on BIM	The share of building components in energy consumption	Reducing energy consumption	2016
Peng	Calculation of a building's life cycle carbon emissions based on BIM	Integrated design and building performance analysis	Improving design quality and Reducing resources consumption	2016
Eguaras-Martínez *et al.*	Simulation and evaluation of Building Information Modeling in a real pilot site	Investigation of real people's behavior in building energy simulation	Energy efficiency	2014
Li *et al.*	Analysis of BIM technology in the Design of Green Village buildings	Building performance analysis	Improving design quality and energy efficiency	2014
Motawa and Carter	Sustainable BIM-based evaluation of buildings	BIM capability to homogenize sustainable buildings	Improving design quality and energy efficiency	2013

consumption index. It should be noted that both Autodesk Green Building Studio and Autodesk Insight software are flexible cloud-based services that allow for simulation of building performance in order to optimize energy efficiency. In addition to the reasons mentioned for choosing the software, it can use the

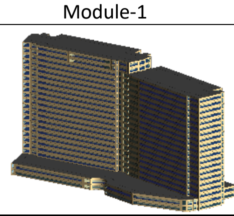
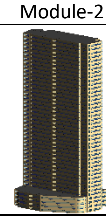
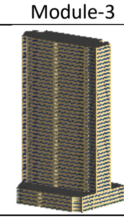
Fig. 1: The 3D view of the simulated building in Autodesk Revit software

minimum hardware resources of the system and provide a very high speed of energy analysis in cloud computing. Fig. 1 shows the 3D view of the building case study in Autodesk Revit software.

RESULTS AND DISSCUSSION

The building case study is a residential complex located in a mild climate zone. The building area is about 101,000 m^2 located in Bandar Anzali, Gilan Province, Iran (37°28'39.5"N, 49°25'11.8"E). The main reason for choosing this building is to study of the form and orientation of the building and the cost changes caused by changing the effective parameters with the aim of optimizing energy consumption using BIM technology. First, three conceptual masses were created to examine various design ideas in the Autodesk Revit software (a top-down design approach). Then, floors, type of materials

Table 2: Comparison of different building forms based on simulation of energy consumption in conceptual masses

	Module-1	Module-2	Module-3
			
Floors	22	43	43
Units	548	560	561
Height (m)	81.70	159.40	159.40

Building Form		Energy cost	Saving	Energy use intensity	Saving
		USD/m^2/y	Percent	kWh/m^2/y	Percent
Module-1	BIM parameters	14	0	113	0
	Optimize parameters	5.96	57.43	80.40	28.85
Module-2	BIM parameters	14.80	0	121	0
	Optimize parameters	7.69	48.04	97.60	19.34
Module-3	BIM parameters	14.30	0	117	0
	Optimize parameters	7.18	49.79	88.80	24.10

and energy settings were defined for each mass. Finally, the results of energy analysis were received after generating the energy model and sending the related file to the Autodesk cloud services. After considering the proposed building design in terms of cost of energy consumption and considering the items such as project location, site scope, building height, facilities and project cost, the first mode of the building form was selected for accurate modeling and energy analysis. Table 2 shows the comparison of different building forms.

Several conceptual masses were first developed to study different design ideas. The closest modes to the actual model of the building and the items such as number of units and area of the building were considered in construction of concept models. Input parameters of the energy model were selected according to the default software (Table 3). The results of the analysis show that the first form of the building has the lowest energy consumption among others. The cost of energy consumption based on the parameters listed in Table 3 is 14 USD/m2/y. Accordingly, the energy consumption is equal to 113 kWh/m2/y (Table 2). In this form, the building orientation is based on the geographical north. Thus, the angle of the building is automatically determined by the software, based on the building form and geographic coordinates of the project. The ratio of windows to north, south, east and west walls is 40% by default. All windows have shades with a depth of 45.72 cm. Also, the type of windows in the conceptual model is double-glazed windows without any external cover. Structure of the walls used in the conceptual model is light with insulation coverage in a mild climate, and the roof structure is light and without insulation. Values of the building infiltration rate, lighting efficiency, plug load efficiency, and operating schedule are adjusted according to the BIM parameter (Table 3). The building's HVAC system is assumed to have a BIM parameter (Residential 14 SEER/0.9 AFUE Split/Packaged Gas <5.5 ton). This building has no day lighting and occupancy control system and photovoltaic solar panels. By adjusting the effective parameters on energy consumption according to Table 4 and Appendix B, the energy cost would be 5.96 USD/m2/y. Accordingly, the energy

Table 3: Basic parameters of the energy model in the conceptual masses

Building form	Module-1	Module-2	Module-3
Energy cost (USD/m^2/y)	14	14.8	14.3
Effective factor	Input parameter		
Building orientation	BIM		
Window-to-Wall ratio (Southern walls)	BIM (40%)		
Window shades (south)	BIM (0.4572 m)		
Window glass (south)	BIM (Double Pane Clear – No Coating)		
Window-to-Wall ratio (Northern walls)	BIM (40%)		
Window shades (north)	BIM (0.4572 m)		
Window glass (north)	BIM (Double Pane Clear – No Coating)		
Window-to-Wall Ratio (Western walls)	BIM (40%)		
Window shades (west)	BIM (0.4572 m)		
Window glass (west)	BIM (Double Pane Clear – No Coating)		
Window-to-Wall ratio (Eastern walls)	BIM (40%)		
Window shades (East)	BIM (0.4572 m)		
Window glass (East)	BIM (Double Pane Clear – No Coating)		
Wall construction	BIM (Lightweight Construction – Typical Mild Climate Insulation)		
Roof construction	BIM (Lightweight Construction – No Insulation)		
Infiltration	BIM (None)		
Lighting efficiency	BIM (10.76 W/m^2)		
Day lighting and occupancy controls	None		
Plug load efficiency	BIM (10.76 W/m^2)		
HVAC	BIM (Residential 14 SEER/0.9 AFUE Split/Packaged Gas <5.5 ton)		
Operating schedule	BIM (24 Hours)		
PV - panel efficiency	None		
PV - payback limit	None		
PV - surface coverage	0%		

use intensity would be equal to 80.4 kWh/m2/y. The building orientation does not change relative to the previous model (base model) and is based on the geographical north. The ratio of windows to the northern and southern walls is 40% by default. These windows have shades as high as 2/3 of the window height. Also, the type of these windows in the conceptual model is triple-glazed windows with low emission. The eastern and western windows have been removed from the conceptual model due to the lack of efficiency.

The walls structure in the conceptual model is according to Table 4, and the roof structure is lightweight and without insulation. The value of the building infiltration rate is 0.17 ACH. The value of the lighting efficiency parameter is assumed to be 3.23 W/m2. The values of the plug load efficiency and the operating schedule are adjusted according to the BIM parameter. The building's HVAC system is assumed to be a high-efficiency variable air volume system. Also, the building has a daylighting and occupancy control system. To achieve the highest level of energy efficiency, the photovoltaic solar panels were used with a yield of 20.4% and surface coverage of 90%. The payback limit of these panels are set at 30 years. Results of this analysis show that the use of BIM technology for adjusting the parameters affecting energy consumption in the conceptual designs can save up to 57.43% energy cost. Based on the energy use intensity, this value would be 28.85%.

Baseline energy model specifications

Depending on analysis tools and specific studies, the building energy model requires a set of parameters. Table 5 shows the basic parameters of the building's energy model as the basis of design. These parameters include: material constructions of building elements and associated thermal properties, HVAC and hot water system types and efficiencies, lighting density and efficiency, building occupancy, plug loads (appliances and electronic devices), internal heat gains from plug loads and occupancy, building natural infiltration rate (air leakage), natural ventilation (the opening and closing of doors and windows), thermostat set-point temperatures, and operating schedules. These parameters are specified

Table 4: Optimization of the parameters effecting energy in the conceptual masses

Building form	Module-1	Module-2	Module-3
Energy cost (USD/m^2/y)	5.96	7.69	7.18
Effective factor		Input parameter	
Building orientation		BIM	
Window-to-Wall ratio (Southern walls)		BIM (40%)	
Window shades (south)		2/3 Win Height	
Window glass (south)		Trp LoE	
Window-to-Wall ratio (Northern walls)		BIM (40%)	
Window shades (north)		2/3 Win Height	
Window glass (north)		Trp LoE	
Window-to-Wall Ratio (Western walls)		(0%)	
Window shades (west)		BIM (No Shade)	
Window glass (west)		BIM (No Window)	
Window-to-Wall ratio (Eastern walls)		(0%)	
Window shades (East)		BIM (No Shade)	
Window glass (East)		BIM (No Window)	
Wall construction		R13+R10 Metal	
Roof construction		BIM (Lightweight Construction – No Insulation)	
Infiltration		0.17 ACH	
Lighting efficiency		3.23 W/m^2	
Daylighting and occupancy controls		Daylighting and Occupancy Controls	
Plug load efficiency		BIM (10.76 W/m^2)	
HVAC		High Eff. VAV	
Operating schedule		BIM (24 Hours)	
PV - panel efficiency		20.4%	
PV - payback limit		30	
PV - surface coverage		90%	

by the BIM title in the provided data.

According to Table 2, the parameters presented in Table 3 were used to examine the various ideas of multi-mass concept design. Then, based on the parameters in Table 4, the main form of the building was selected after reviewing the proposed designs. After creating the building model (current condition of the building), energy analysis was performed based on the parameters presented in Table 5. Finally, the lowest energy consumption in the building was achieved by setting the parameters effecting energy consumption.

Building energy simulation and data analysis

BIM data export process

After modeling and adjusting the parameters required in the Autodesk Revit software (Table 5), the energy model was created using the analyze tab (Fig. 2). Then, an Autodesk account was used to send the energy model and receive the data analysis results. It should be noted that by sending the energy model through the Autodesk Revit software to the Autodesk Insight software, the energy model is simultaneously sent to the Autodesk Green Building Studio software.

Climate data

After sending the energy model, the climate data, as the first element of the environment in which the building is located, were automatically taken from the nearest weather station database (Table. 6).

The data related to design conditions based on the dry-bulb temperature and the Mean Coincident Wet Bulb (MCWB) temperature are shown in Table 7. Fig. 3 shows the average daily minimum and maximum temperatures on a monthly basis.

Solar orientation study

Solar radiation on building surfaces were investigated. The results indicated that block D (located on the eastern side of the site), with the most sunlight received during the day, had a better position compared to block C. The frequency distribution diagrams of total sky cover, direct normal radiation, diffuse horizontal radiation, and global horizontal radiation are shown in Fig. 4 based on annual data.

Analysis the parameters affecting energy

Fig. 5 for block D shows the highest energy cost in July. It is obvious that ventilation fans and space cooling have the highest share compared to other

Table 5: Basic parameters of the building's energy model

Input parameter	Value
HVAC system	Residential 14 SEER/0.9 AFUE Split/Packaged Gaz < 5.5 ton
Area per person	105.82 m^2
Sensible heat gain (per person)	73.27 W
Latent heat gain (per person)	58.61 W
Power load density	10.76 W/m^2
Lighting load density	10.76 W/m^2
Plenum lighting contribution	20%
Occupancy schedule	24 Hours
Lighting schedule	All Day
Power schedule	All Day
Outdoor air (per person)	2.36 L/s
Outdoor air (per area)	0.30 $L/(s.m^2)$
Unoccupied cooling set point	27.78 °C
Infiltration (ac/h)	None
Fabric *U*-values	
External walls	20cm concrete block (*U*-value 6.5 W/m^2K)
Internal walls	10cm concrete block (*U*-value 13 W/m^2K)
Shear walls	45cm reinforced concrete (*U*-value 2.3244 W/m^2K)
Floor	22.5cm concrete slab (*U*-value 4.6489 W/m^2K)
External doors	Wooden, Single-Flush (*U*-value 2.1944 W/m^2K)
Terrace doors	Wood frame with single clear glass (*U*-value 5.6212 W/m^2K)
Lobby doors	Metal frame with single clear glass (*U*-value 6.5580 W/m^2K)
Elevator doors	Metal (*U*-value 3.7021 W/m^2K)
Windows	1/8 in Pilkington single glazing (*U*-value 3.6886 W/m^2K)

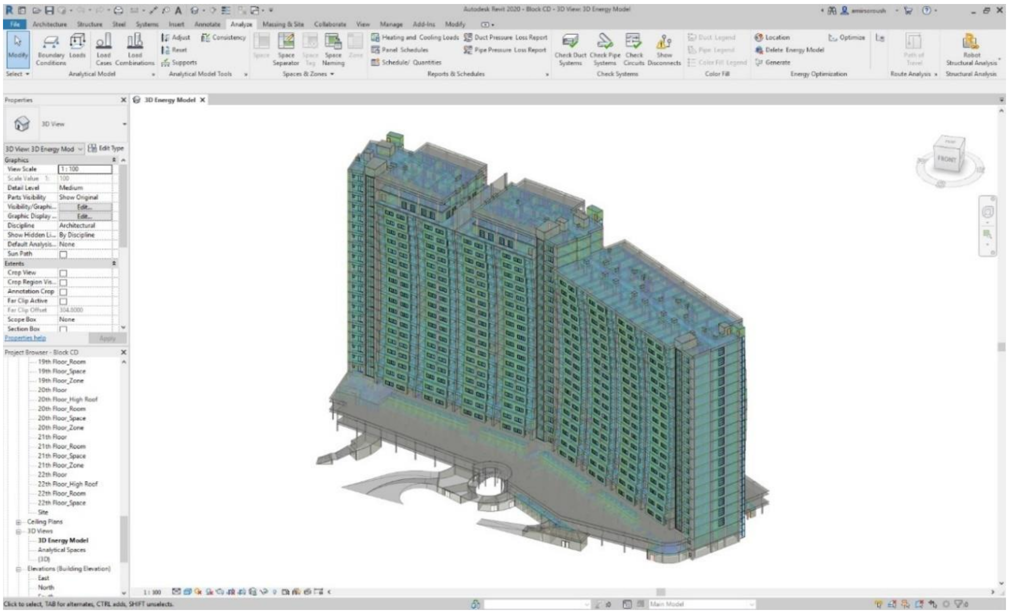


Fig. 2: Creating the energy model using building elements in Autodesk Revit software

Table 6: Temperature data from the nearest weather station database

Weather Station: GBS_06M12_12_002300
Distance to your project 474.2 mi (763.2 km)
Latitude = 36.4167 , Longitude = 58.1500

IP SI

Cooling Degree Day		Heating Degree Day	
Threshold	Value	Threshold	Value
18.3 °C	1110	18.3 °C	2047
21.1 °C	657	15.6 °C	1577
23.9 °C	316	12.8 °C	1172
26.7 °C	104	10 °C	807

Table 7: The dry-bulb and the mean coincident wet bulb (MCWB) temperature based on annual data

IP SI

Annual Design Conditions				
Threshold	Cooling		Heating	
	Dry Bulb(°C)	MCWB(°C)	Dry Bulb(°C)	MCWB(°C)
0.1 %	39.2	18.1	-10.4	-11.3
0.2 %	38.8	17.9	-9.8	-11.0
0.4 %	38.4	17.9	-9.2	-10.4
0.5 %	38.2	18.0	-8.8	-9.8
1 %	37.3	17.3	-7.6	-8.9
2 %	36.4	16.9	-4.8	-6.5
2.5 %	36.0	16.7	-3.9	-5.7
5 %	34.1	15.8	-1.9	-3.7

parameters affecting energy consumption.

The maximum energy use intensity in block D is observed in January (Fig. 6). Obviously, space heat and ventilation fans have the highest share among other parameters. Accordingly, the highest level of energy consumption based on energy cost is seen in July and August and based on energy use intensity is seen in January and December. The schematic diagrams of energy consumption for block C and the western lobby are similar.

The results show that block D has the lowest energy consumption after optimization. Based on the parameters presented in Table 8, the cost of energy consumption for block C is 13.6 USD/m2/y. This value for both block D and the western lobby is 14.1. Accordingly, the energy use intensity for blocks C, D, and the western lobby would be 126, 119, and 191 kWh/m2/y, respectively (Table 10). The building orientation, in this case, is based on the geographical north. Thus, angle of the building is automatically determined by the software, based on the building form and the project geographic coordinates. The windows ratios to the northern, southern, eastern and western walls are 21%, 23%, 7%, and 8%, respectively. These values are 21%, 21%, 5%, and 10% for block D, and 15, 25, 13, and 14% for the western lobby, respectively. The shades of all windows are considered by default. Therefore, the windows installed on the terraces would use their overhead ceiling as a shade. Other windows installed

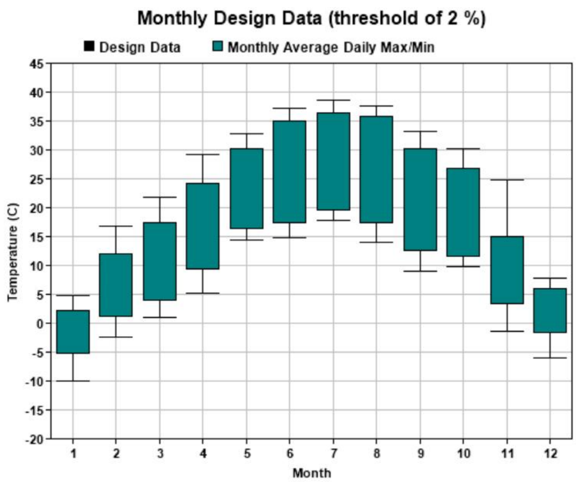


Fig. 3: Average maximum and minimum daily temperatures on a monthly basis

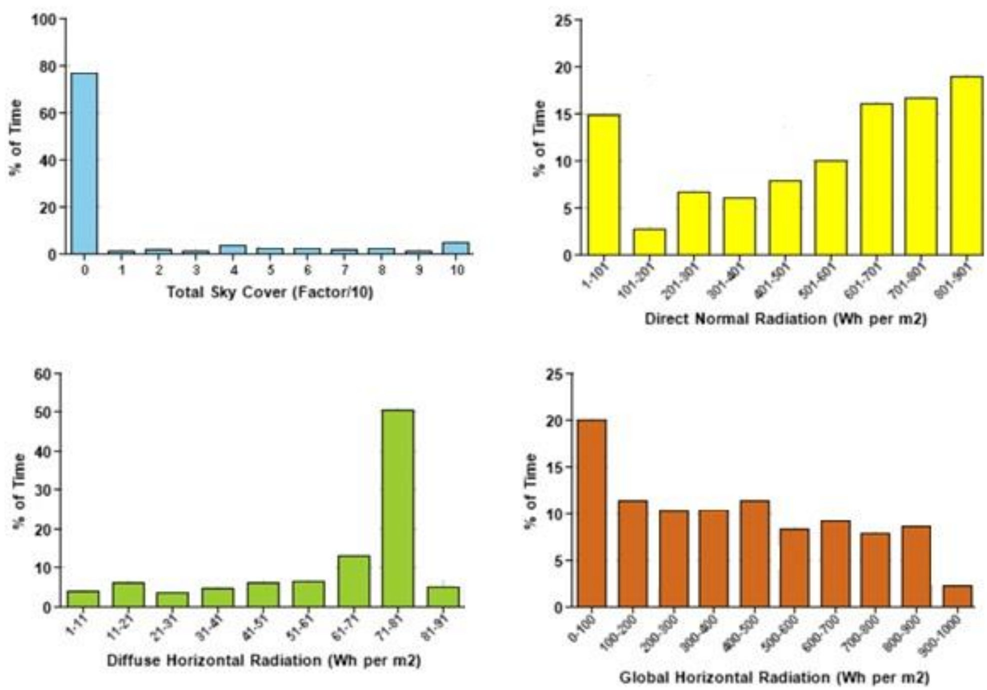


Fig. 4: Top left) Total sky cover frequency distribution; Top right) Direct normal radiation frequency distribution; Bottom left) Diffuse horizontal radiation frequency distribution; Bottom right) Global horizontal radiation frequency distribution

on the external walls surfaces lack a shading system. Also, the type of windows is based on the software-defined element (single clear glass). The walls and roof structure are shown in Tables 5 and 6. The values of the building infiltration rate, lighting efficiency, plug load efficiency, and operating schedule are adjusted according to the BIM parameter (Table 6). The building's HVAC system is assumed to have a BIM parameter (Residential 14 SEER/0.9 AFUE Split/Packaged Gas <5.5 ton). This building has no daylighting and occupancy control system and photovoltaic solar panels.

Energy analysis was performed after creating the building model based on the parameters in Table 5. The results presented in Table 8 are based on the software output. The lowest energy consumption in the building can be obtained by setting the parameters affecting energy consumption (Table 9). After adjusting the parameters affecting energy consumption, the energy cost of block D was found to be 5.89 USD/m2/y. This value for block C is 6.66 and for the western lobby is 8.03. Accordingly, the values of energy use intensity for blocks C, D, and the western lobby would be equal to 105, 99.6, and 170 kWh/m2/y, respectively. The building orientation relative to the previous model (base model) is unchanged and is based on the geographical north. The windows ratios to the northern and southern walls are unchanged and equal to 21% and 23% for block C, 21% for block D, and 15% and 25% for the western lobby, respectively. For all blocks, the northern window shades are considered by default. Moreover, the southern window shades are selected as high as 2/3 of the window height. The type of northern windows is determined based on the software-defined element (single clear glass) for all blocks. The triple-glazed type with low emission was

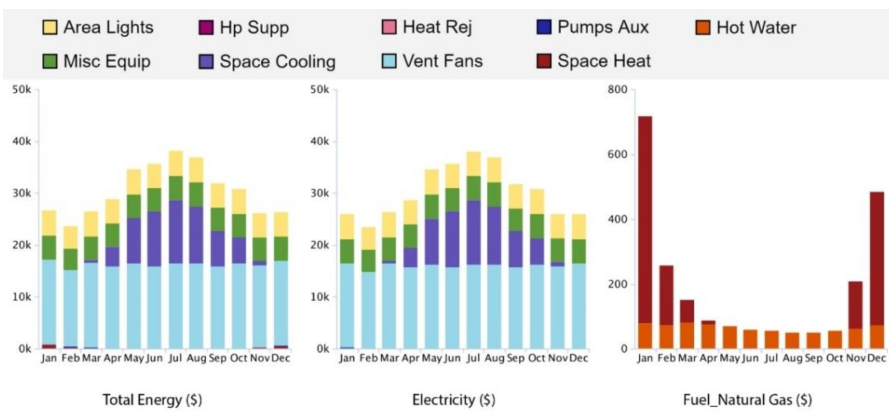


Fig. 5: Energy consumption index based on energy cost, Block D

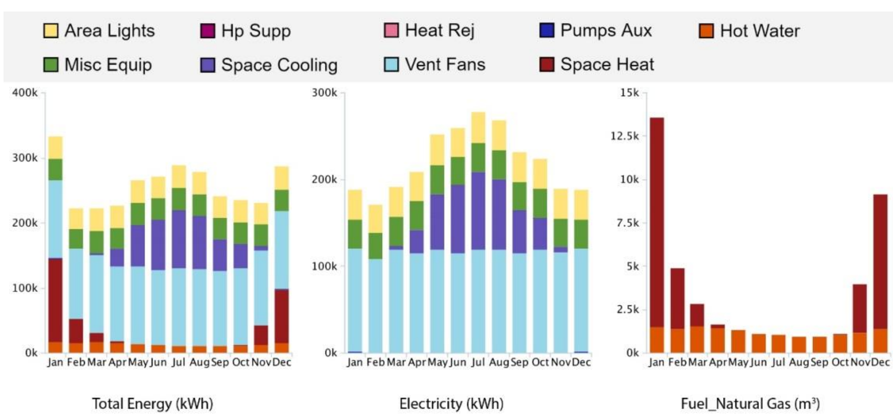


Fig. 6: Energy consumption index based on energy use intensity, Block D

Table 8: Basic parameters of building energy consumption

Building form	Block C	Block D	Western lobby
Energy cost (USD/m^2/y)	13.6	14.1	14.1
Effective factor		Input parameter	
Building orientation		BIM	
Window-to-Wall ratio (Southern walls)	BIM (23%)	BIM (21%)	BIM (25%)
Window shades (south)		BIM	
Window glass (south)		BIM (Sgl Clr)	
Window-to-Wall ratio (Northern walls)	BIM (21%)	BIM (21%)	BIM (15%)
Window shades (north)		BIM	
Window glass (north)		BIM (Sgl Clr)	
Window-to-Wall Ratio (Western walls)	BIM (8%)	BIM (10%)	BIM (14%)
Window shades (west)		BIM	
Window glass (west)		BIM (Sgl Clr)	
Window-to-Wall ratio (Eastern walls)	BIM (7%)	BIM (5%)	BIM (13%)
Window shades (East)		BIM	
Window glass (East)		BIM (Sgl Clr)	
Wall construction		BIM (Concrete Masonry Units)	
Roof construction		BIM (Concrete, Cast In Situ)	
Infiltration		BIM (None)	
Lighting efficiency		BIM (10.76 W/m^2)	
Daylighting and occupancy controls		None	
Plug load efficiency		BIM (10.76 W/m^2)	
HVAC		BIM (Residential 14 SEER/0.9 AFUE Split/Packaged Gas <5.5 ton)	
Operating schedule		BIM (24 Hours)	
PV - panel efficiency		None	
PV - payback limit		None	
PV - surface coverage		0%	

chosen to be used in southern windows. The eastern and western windows have been removed from the building model due to lack of efficiency. The walls and roof structure are shown in Table 9. The value of the building infiltration is 0.17 ACH. The value of the lighting efficiency is assumed to be 3.23 W/m2. The values of plug load efficiency and operating schedule are adjusted according to the BIM parameter. The building's HVAC system is assumed to be a high-efficiency variable air volume system. Moreover, the building has a daylighting and occupancy control system. To achieve the highest energy efficiency, the photovoltaic solar panels, with a yield of 20.4% and surface coverage of 90%, were used. The payback limit of these panels was assigned as 30 years. Depending on the analysis tool, the building energy model may need a set of parameters. According to Table 5, the input parameters entered the software by default. Thus, variables of the proposed model were also received as output from the software (Table 9).

Table 10 shows that employing the BIM technology for adjusting the parameters affecting energy consumption can save up to 58.23% energy cost for block D. This value is 51.03% for block C and 43.05% for the western lobby. However, based on energy use intensity, this value would be 16.67%, 16.30%, and 11% for blocks C, D, and the western lobby. The saving based on energy cost can be calculated by Eq. 1 and the saving based on energy use intensity can be estimated using Eq. 2.

$$\left(\frac{5.89}{14.10}-1\right)*100=-58.23\% \tag{1}$$

$$\left(\frac{99.60}{119}-1\right)*100=-16.30\% \tag{2}$$

As previously mentioned, the building blocks are separated from each other and the ceiling element has been removed from the building model, due to the software limitations in sending the energy model. Therefore, the computational height is 4 m on the first floor and 3.70 m in other floors. This building could have lower energy consumption values than the obtained values, due to the implementation of ceiling element during the construction phase and reduced

Table 9: Optimization of the parameters effecting building energy consumption

Building form	Block C	Block D	Western lobby
Energy cost (USD/m²/y)	6.66	5.89	8.03
Effective factor		Input parameter	
Building orientation		BIM	
Window-to-Wall ratio (Southern walls)	BIM (23%)	BIM (21%)	BIM (25%)
Window shades (south)		2/3 Win Height	
Window glass (south)		Trp LoE	
Window-to-Wall ratio (Northern walls)	BIM (21%)	BIM (21%)	BIM (15%)
Window shades (north)		BIM	
Window glass (north)		BIM (Sgl Clr)	
Window-to-Wall Ratio (Western walls)		(0%)	
Window shades (west)		BIM (No Shade)	
Window glass (west)		BIM (No Window)	
Window-to-Wall ratio (Eastern walls)		(0%)	
Window shades (East)		BIM (No Shade)	
Window glass (East)		BIM (No Window)	
Wall construction		R13+R10 Metal	
Roof construction		BIM (Concrete, Cast In Situ)	
Infiltration		0.17 ACH	
Lighting efficiency		3.23 W/m²	
Daylighting and occupancy controls		Daylighting and Occupancy Controls	
Plug load efficiency		BIM (10.76 W/m²)	
HVAC		High Eff. VAV	
Operating schedule		BIM (24 Hours)	
PV - panel efficiency		20.4%	
PV - payback limit		30	
PV - surface coverage		90%	

Table 10: Comparison of different energy consumption scenarios in the building blocks

Building bock		Energy cost	Saving	Energy use intensity	Saving
		USD/m²/y	Percent	kWh/m²/y	Percent
C	BIM parameters	13.60	0	126	0
	Optimize parameters	6.66	51.03	105	16.67
D	BIM parameters	14.10	0	119	0
	Optimized parameters	5.89	58.23	99.60	16.30
Western lobby	BIM parameters	14.10	0	191	0
	Optimized parameters	8.03	43.05	170	11

computational height of the spaces as a result. However, the results show that block D has the lowest energy consumption. Considering the similar materials and equipment used, this can be due to the building orientation towards the actual north of the region (geographic north). Accordingly, by implementation of block C along block D, the lowest energy consumption can be achieved as a result of the maximum solar radiation during the day. This study shows that the results from the conceptual model analysis are more acceptable compared to the results from the actual building model. This can be useful in the early stages of decision-making for the project.

CONCLUSION

Most of the current environmental problems are related to the use of fossil fuels, especially in the construction sector. In Iran, a large amount of energy is annually consumed in the building and housing sectors. In this study, energy performance assessment was carried out based on the Building Information Modeling technology (BIM-EPAs) and it was found that application of this technology can lead to design identification, comparison, and reduction of energy consumption in the early stages of design. The aim of this study was to investigate the parameters affecting energy consumption using the Building Information Modeling (BIM) technology. After reviewing the proposed designs and choosing the building form, an exact model of building elements was created in the Autodesk Revit software. Then, the energy model was generated based on the basic parameters. The results showed that application of the building information modeling technology for adjusting the parameters affecting energy consumption would save up to 58.23% energy cost for block D. This value was 51.03% for block C and 43.05% for the western lobby. As a result, this value would be 16.67%, 16.30% and 11% for blocks C, D, and the western lobby, respectively, based on the energy use intensity. Finally, adjusting the energy-efficient parameters led to reduction of energy cost in the building. The energy simulation results showed that 16.30% saving would be achieved based on energy use intensity for the base building model in a 30-year time horizon.

AUTHOR CONTRIBUTIONS

N. Amani performed the methodology, investigation, validation, conceptualization, and supervision. A.A. Reza Soroush performed the literature review, data collection, software, and writing the original draft.

ACKNOWLEDGEMENTS

This study was supported by the Chalous Branch, Islamic Azad University for a postgraduate thesis.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

ABBREVIATIONS

ACH	Air Changes per Hour
AFUE	Annual Fuel Utilization Efficiency
BIM	Building Information Modeling
CM	Centimeters
E	East
EFF	Efficiency
HVAC	Heating, ventilation, and air conditioning
K	Thermal conductivity of the material
kWh	kilowatt-hour
$kWh/m^2/y$	kilowatt-hour per square meter per year
L	Liter
L/s	Liter per second
$L/(s.m^2)$	Liter per second to square meter
M	Meter
M^2	Square meter
N	North
R13+R10	American energy codes
S	Second
SEER	Seasonal Energy Efficiency Ratio
SGL	Standard General Ledger
USD	United State Dollar
USD/m2/*y*	United State Dollar per square meter per year
VAV	Variable Air Volume
W	Watt
W/m^2	Watt per square meter
W/m^2K	Watt per square meter per thermal conductivity of the material
y	Year
%	Percent
$	Dollar
^oC	degree Celsius

REFERENCES

Abanda, F.H.; Byers, L., (2016). An investigation of the impact of building orientation on energy consumption in a domestic building using emerging BIM (Building Information Modelling). Energy. 97: 517–527 **(11 pages).**

Banteli, A.; Stevenson, V.E., (2017). Building information modelling (BIM) as an enabler for whole-building embodied energy and carbon calculation in Early-Stage building design. WIT Trans. Built Environ., 169: 89–100 **(12 pages).**

Beazley, S.; Heffernan, E.; McCarthy, T.J., (2017). Enhancing energy efficiency in residential buildings through the use of BIM: The case for embedding parameters during design. Energy Procedia, 121: 57–64 **(8 pages).**

Cemesova, A.; Hopfe, C.J.; McLeod, R.S., (2015). Passive BIM: Enhancing interoperability between BIM and low energy design software. Autom. Constr., 57: 17–32 **(16 pages).**

Choi, J.; Shin, J.; Kim, M.; Kim, I., (2016). Development of open BIM-based energy analysis software to improve the interoperability of energy performance assessment. Autom. Constr., 72: 52–64 **(13 pages).**

Eguaras-Martínez, M.; Vidaurre-Arbizu, M.; Martín-Gómez, C., (2014). Simulation and evaluation of building information modeling in a real pilot site. Appl. Energy, 114: 475–484 **(10 pages).**

Egwunatum, S.; Joseph-Akwara, E.; Akaigwe, R., (2017). Assessment of energy utilization and leakages in buildings with building information model energy. Frontier. Architect. Res., 6(1): 29–41 **(13 pages).**

Farzaneh, A.; Monfet, D.; Forgues, D., (2019). Review of using Building Information Modeling for building energy modeling during the design process. J. Build. Eng., 23: 127–135 **(9 pages).**

Gao, H.; Koch, C.; Wu, Y., (2019). Building information modelling based building energy modelling: A review. Appl. Energy, 238: 320–343 **(24 pages).**

Gerrish, T.; Ruikar, K.; Cook, M.; Johnson, M.; Phillip, M.; Lowry, C., (2017). BIM application to building energy performance visualisation and management Challenges and potential. Energy Build., 144: 218–228 **(11 pages).**

Guo, S.J.; Wei, T., (2016). Cost-effective energy saving measures based on BIM technology: Case study at National Taiwan University. Energy Build., 127: 433–441 **(9 pages).**

Habibi, S., (2017). The promise of BIM for improving building performance. Energy Build., 153: 525–548 **(24 pages).**

Jung, D.K.; Lee, D.H.; Shin, J.H.; Song, B.H.; Park, S.H., (2013). Optimization of energy consumption using BIM-based building energy performance analysis. Appl. Mech. Mater., 281: 649–652 **(4 pages).**

Kim, J.B.; Jeong, W.; Clayton, M.J.; Haberl, J.S.; Yan, W., (2015). Developing a physical BIM library for building thermal energy simulation. Autom. Constr., 50: 16–28 **(13 pages).**

Kovacic, I.; Zoller, V., (2015). Building life cycle optimization tools for early design phases. Energy, 92: 409–419 **(11 pages).**

Kurian, C.P.; Milhoutra, S.; George, V.I., (2016). Sustainable building design based on building information modeling (BIM). 2016 IEEE International Conference on Power System Technology; POWERCON, 1–6 **(6 pages).**

Li, Y.F.; Wang, H.C.; Zhao, M., Pan, W.Y., (2014). Analyses on the BIM Technology Using in the Design of Green Village Buildings. Appl. Mech. Mater., 548–549: 1758–1762 **(5 pages).**

Maltese, S.; Tagliabue, L.C.; Cecconi, F.R.; Pasini, D.; Manfren, M.; Ciribini, A.L.C., (2017). Sustainability Assessment through Green BIM for Environmental, Social and Economic Efficiency. Procedia Eng., 180: 520–530 **(11 pages).**

Ministry of Energy, (2016). Energy balance sheet, Office of Planning and Economics of Electricity and Energy. (In Persian).

Motawa, I.; Carter, K., (2013). Sustainable BIM-based Evaluation of Buildings. Procedia Soc. Behav. Sci., 74: 419–428 **(10 pages).**

Najjar, M.; Figueiredo, K.; Hammad, A.W.A.; Haddad, A., (2019). Integrated optimization with building information modeling and life cycle assessment for generating energy efficient buildings. Appl. Energy, 250: 1366–1382 **(17 pages).**

Nizam, R.S.; Zhang, C.; Tian, L., (2018). A BIM based tool for assessing embodied energy for buildings. Energy Build., 170: 1–14 **(14 pages).**

Peng, C., (2016). Calculation of a building's life cycle carbon emissions based on Ecotect and building information modeling. J. Clean. Prod., 112: 453–465 **(13 pages).**

Pérez-Lombard, L.; Ortiz, J.; Pout, C., (2008). A review on buildings energy consumption information. Energy Build., 40(3): 394–398 **(5 pages).**

Schlueter, A.; Thesseling, F., (2009). Building information model based energy/exergy performance assessment in early design stages. Autom. Constr., 18(2): 153–163 **(11 pages).**

Shivsharan, A. S.; Vaidya, R.; Shinde, R. D., (2017). 3D Modeling and energy analysis of a residential building using BIM tools. Int. Res. J. Eng. Tech., 4(7): 629-636 **(8 pages).**

Singh, P.; Sadhu, A., (2019). Multicomponent Energy Assessment of Buildings using Building Information Modeling. Sustainable Cities Soc., 49: 1-12 **(12 pages)**.

Venkataraman, A.; Kannan, R., (2013). Whole Building Energy Analysis using BIM. Proceeding of International Conference on Advances in Civil Engineering; AETACE, 935-943 **(9 pages).**

AUTHOR (S) BIOSKETCHES

Amani, N., Ph.D., Assistant Professor, Department of Civil Engineering, Chalous Branch, Islamic Azad University, Chalous, Iran.
Email: *nimaamani@iauc.ac.ir*

Reza Soroush, A.A., M.Sc., (2020). Department of Civil Engineering, Chalous Branch, Islamic Azad University, Chalous, Iran.
Email: *amir.soroush57@gmail.com*

HOW TO CITE THIS ARTICLE

Amani, N.; Reza Soroush, A.A., (2020). Effective energy consumption parameters in residential buildings using Building Information Modeling. Global J. Environ. Sci. Manage., 6(4): 467-480.

DOI: 10.22034/gjesm.2020.04.04

url: https://www.gjesm.net/article_39209.html