Journal of Sustainability Perspectives

journal homepage: https://ejournal2.undip.ac.id/index.php/jsp/

Energy Performance Analysis of a Multi-Story Building Using Building Information Modeling (BIM)

Syed Shujaa Safdar Gardezi, Syed Haris Ali, Raheel Fayaz, Huzaifa Hassan Shah*
Department of Civil Engineering, Capital University of Science & Technology (CUST), Zone-V 44000 Islamabad, Pakistan
*corresponding author: dr.shujaasafdar@cust.edu.pk

Article Info

Received:
14 March 2022
Accepted:
25 May 2022
Published:
30 June 2022

DOI:
10.14710/jsp.2022.15459

Selected papers from the 7th International (Visual) Workshop on UI Greenmetric World University Rankings (IWGM 2021)

Abstract. There is an enormous rise in building construction to meet serious demands of population increase. Besides its benefits, certain negative impacts on climate change and environments are associated with the built environment due to substantial energy requirements during operational phase. The current work aims to assess the energy consumption pattern of a residential facility based upon solar path analysis using simulation technique. A multi-story conventional building has been developed in a virtual 3D parametric environment using building information modeling. The BIM model was converted into the energy model using cloud computing. The energy model, at the proposed current orientation, was analyzed using insight 360 and solar energy analysis performed accordingly. Based upon the solar path analysis, the study observed that, at the present trajectory of solar path, provision of solar panels arrangements on 106,221 ft^2 Photovoltaic panel area can produce the energy of 2,163,417 kwh/year with a payback period of 0.8 years.

Keyword:
Building Information Modelling, Energy analysis, Energy Optimization, Architecture 2030 Challenge

1. Introduction

Construction Industry is the major source of emission of CO_2 and many other radiations. Natural recourses of world are depleting at faster rate. Due to this utilization of natural recourse, there is the surge in the climate of the word. Environmental issues and high rise in cost of energy have increased demand for the sustainable construction which will have minimum effect on the environment. Energy consumption is one of the main reasons for the environmental instability throughout the world. This environmental instability affects the health of the public. Almost about 90% of a building's environmental effect results from the energy that a building uses during its lifetime [1].

Energy analysis helps to investigate the consumption of energy in, out, and through the internal rooms in a designed building model. This information can be beneficial for designers to be informed, make cost-effective decisions that help to improve the performance and lower down the environmental effects due to the buildings. Total building energy analysis performed, calculates probable energy use (fuel and electricity) based on the building's geometry, orientation, climate, building type, and active systems (HVAC & Lighting) [2]. To reduce and minimize this effect on the environment, solar energy analysis is one of the preemptive strategies to estimate and evaluate the effects of solar energy. It can guide to assess and utilize energy in such a way that the annual energy consumption can be managed.

Solar energy analysis is performed on the structure through all phases, starting from the initial complex phase through detailed design, to observe that user is continuously working towards the energy efficient building. It considers the inter relations of different phases of analysis as a whole system. Besides many other solutions for sustainability, building information modeling (BIM) is one of the processes to perform energy simulation for conceptual arrangements and detailed architectural models in a virtual environment. This results from simulation help in understanding building energy use, then iterate the design to improve the sustainability ratings.

About 46% of all energy used in the Pakistan are consumed by the buildings which is one of the highest consumptions in the domestic sector [3]. The current works aims to assess sun path energy analysis of conventional multistorey building using building information modeling (BIM). This will lead to modify architectural design of a building that will reduce the annual energy utilization. Environmental legislation is trying to convince builders, planners and architects to consider impact of the designed or constructed building on environment. All this required to avoid the environmental impacts of building sector on climate resulting in greenhouse gas emissions, rise in temperature and sudden environmental changes etc. [4]

2. Literature

Environment challenges and ecological difficulties have become significant concern. The researchers, planner and designer are merging energy performance of building to make a suitable result that increasing affordable and feasible toward society. Energy examination with the assistance of BIM has gotten prominent in late decades and it has helped designers and draftsmen to make thinking about the impacts of structure to environment. Building Information Modeling (BIM) informs about the procedure of improvement and how to be able to utilize of a model to find out the arranging, structure, development and activity of a building. BIM incorporates related advantages of perception, worked in practicality objects of a building model, such as, three-dimensional information (3D), unstructured information (message), and planned information, for example, databases and spreadsheets. BIM models not just give information relating to the structure geometry, yet they permit the count of capacities and correlated energy dependent taking place the qualities and direction of a structure. Table 1 summarize some studies conducted for performance analysis using BIM.

Table 1. Studies conducted for performance analysis using BIM by different researchers

Researcher	Year	Country	Type of study
Elnabawi [5]	2020	Egypt	Building Information Modelling-Based Building Energy Modelling: Investigation of Interoperability and Simulation Results
Mishra and Goel [6]	2019	India	Energy Analysis of High Rise Building integrated with BIM
Sandberg, Mukkavaara [7]	2019	Sweden	Multidisciplinary Optimization of Life-Cycle Energy and Cost Using a BIM-Based Master Model
Kim, Hadadi [8]	2018	Australia	Development of A BIM-Based Maintenance Decision-Making Framework for the Optimization between Energy Efficiency and Investment Costs
Lu, Wu [9]	2017	China	Analysis Building Information Modeling (BIM) for green buildings
Kuo, Hsieh [10]	2016	Taiwan	A verification study for energy analysis of buildings with BIM
Gardezi, Shafiq [11]	2013	Malaysia	Prospects of Building Information Modeling (BIM) in Malaysian construction Industry as Conflict Resolution Tool
Díaz-Vilariño, Lagüela [12]	2012	Spain	As-Built BIM with shades modeling for Energy
Cho, Chen [13]	2012	Korea	Building Information Modeling (BIM) based design of energy efficient buildings
Stumpf, Kim [14]	2011	USA	Early Design Energy Analysis Using Building Information Modeling Technology

3. Methodology

A sixteen-story building was selected as a case study to do the sun-path analysis. The building is in the Capital. This was a sixteen-story building with a covered area of 188,000 sft and height of 184 ft. The ground and first floor plan were unique whereas the above floor followed same typical plan. There are six apartments on each floor. A 3D parametric architectural model was created in Revit Architecture which was later subjected to insight to make an energy model, figure 1.

Figure 1. Perspective View of 3-D Virtual Model

Energy performance analysis (EPA) is basically a pre-construction analysis of a building to find out its energy consumption on a yearly basis. Energy Model generated after analysis, figure 2, shows three different colors on the building yellow, red, and grey. The area on which sunlight strikes the most is in yellow color and the very little sun light incident on the area which is red and the area in grey show no effect of sunlight.

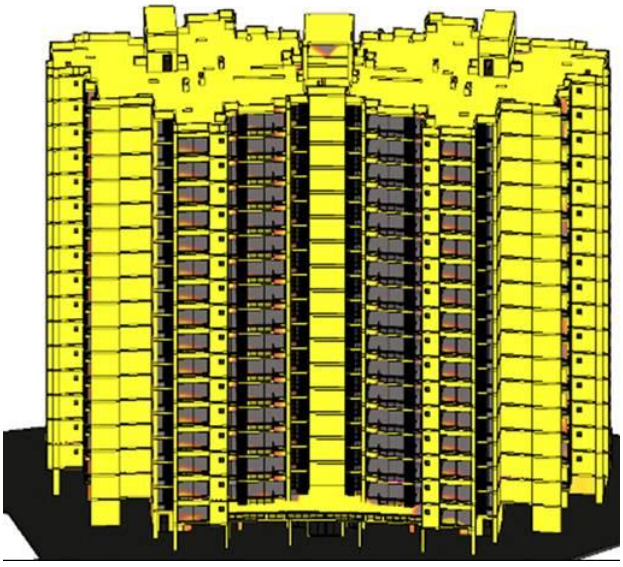


Figure 2. Energy Model

Solar path analysis was performed, related to the sun light. There are two components of Solar Analysis i.e., i) Photovoltaic (PV) and ii) sun path analysis. The Solar Analysis offers analysis in a real-time with time and date, climate, location and temperature. The model was provided with the solar path, figure 3. Solar path. The data included the overall information about the model selected area, type of analysis selected whether its insulation or PV annual solar analysis.

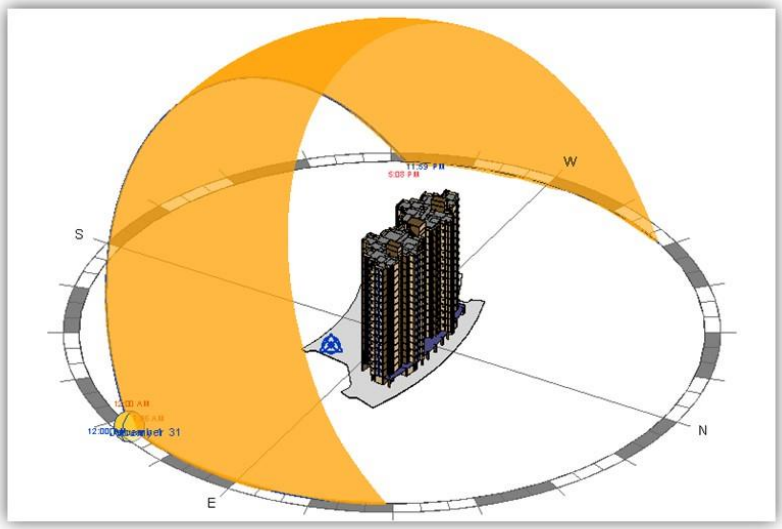


Figure 3. Sun Path

Analysis was done on insight-360 under the solar analysis domain on as-built orientation. This was mainly due to the following two reasons.

- The building was under-construction and its orientation could not be changed
- To know the importance of EPA whether it provides better decisions regarding sustainability of the facility.

Weather data was based on the project location, electricity cost in Pakistan for the year 2020 was incorporated. Analysis grid option was set to default as it indicated the number of points on each grid of the whole mesh simulated, table 2.

Table2. Study Setting Data

Weather Data	Analysis Period	Electricity Cost	Panel Type	Coverage	Payback Filters	Analysis Grid
ID 711278 Islamabad, Pakistan	Full Annual	17.67 PKR* 0.11 $-USD	16.0% $2.86/Installed Watt	100% selected Surface	50 years payback limit	2.24-foot grid

*Electricity cost in Pakistan form January -May 2020

Complete building was selected for analysis purpose. Solar energy analysis was performed with the specifications and setting and sun path in figure 3. One-day solar study was selected. These setting could be changed based on the design criteria and real-life data input for instance time frame, weather, and location of the project

4. Results

The energy model generated after the analysis highlighted annual energy production i.e., 2,163,417 kWh/year with the PV panel area of 106,221 m^2 and payback period of almost one year, Figure 4.

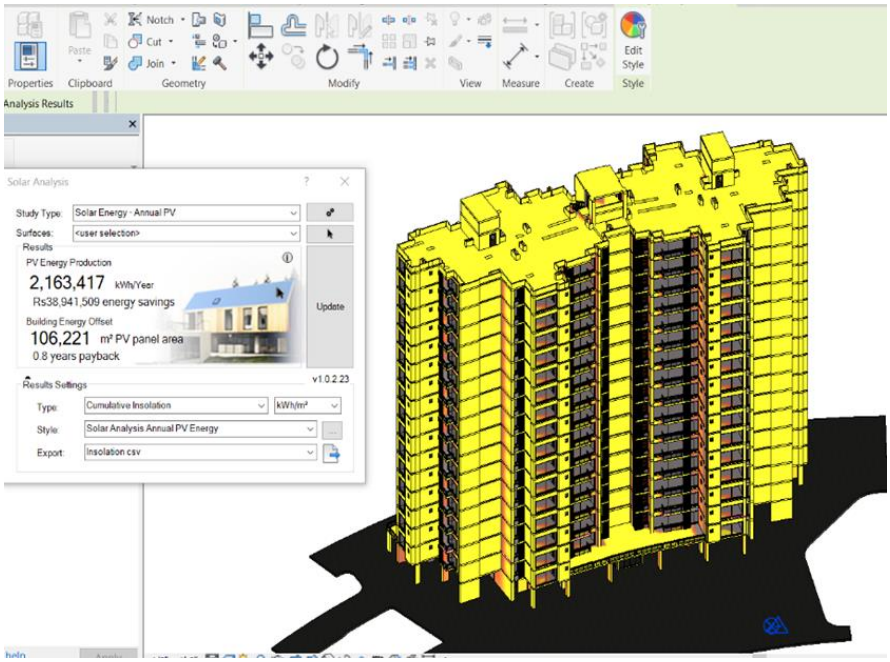
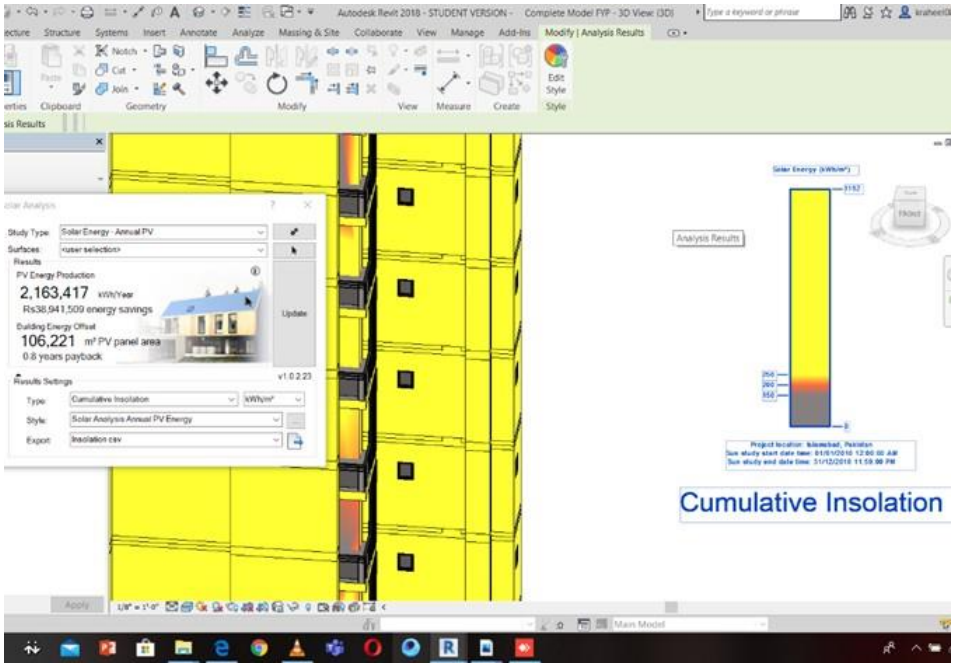


Figure 4. Results generated using Insight

These results might differ with respect to the orientation of building as well as the applied sun and energy settings. Energy bar, figure 5, can be used to focus on the areas where maximum energy is generated for instance the bar ranges between (0 -1152 kWh/m^2) with the specific color code grey (0-150 kWh/m^2), red (151-200 kWh/m^2) and yellow (250 – 1152 kWh/m^2) value. These values in the color schemes can be used to find and analyze the energy difference among the various faces of the building. The level of details required, depend on the scope of work.



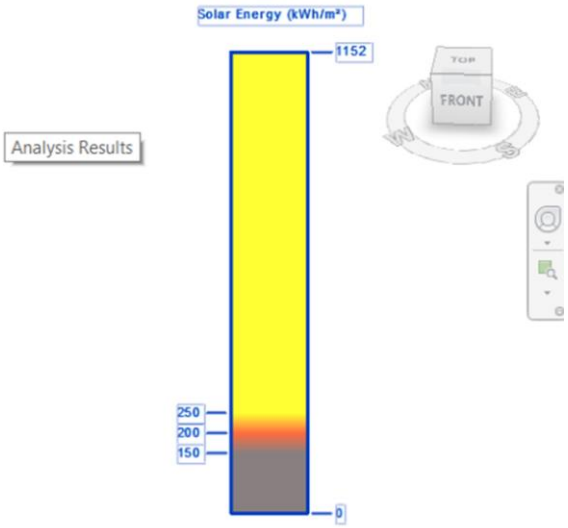


Figure 5.Energy Model with Energy Bar

5. Conclusion and Recommendations

Based upon the outcome of the study, it has been concluded that

- The energy generation depends on various factors such as orientation of the building, sun path setting, energy setting, location, and weather data.
- During analysis, complete building was selected that is why the payback period is 0.8 years while building orientation was kept fixed. However, in reality, such results might be hard to achieve therefore in order to achieve the practically feasible results a number of different combinations would be required for analysis by selecting different combination of faces of building feasible to Photovoltaic panel areas and comparing the results for the most feasible one.
- The results obtained in this research may not be adoptable for any other building because the pre-defined energy setting differ region to region and building to building.

Solar energy analysis for annual PV is performed on as-built orientation of the building and got positive results showing the annual energy production by providing solar panel area which can be utilized to place solar panels in the building during actual construction. Moreover, it gives energy saving cost based on the annual energy production, PV panel area and the electricity cost. The payback period and electricity cost are adjustable prior to analysis based on the contextual environment which varies from country to country. The study recommends the following as guideline for further studies:

- The results obtained can be compared with any other building with same or quite similar specifications. However, standardization may not be advisable due to limitations of various unique parameters pertaining to individual building facilities.
- This research was focused on solar analysis of conventional building using insight 360. Other softwares are available which could also be used for energy simulation such as Green Building Studio. A comparison of the results with insight results is advised to go the feasible and sustainable solution.

Energy simulation results can be enhanced by broadening the scope in such a way that it should include day light analysis, heating and cooling (H&C) analysis and different combination of solar, day light and H&C analysis. This would lead a better decision to support sustainable development.

Acknowledgment
The authors would like to thank Capital University of Science and Technology, BIM Center of Excellence and the organizations for their support to complete this research work.

References

1. Chastas, P., T. Theodosiou, and D. Bikas, Embodied energy in residential buildings-towards the nearly zero energy building: A literature review. Building and Environment, 2016. 105: p. 267-282.
2. Shivsharan, A., M.D. Vaidya, and R. Shinde, 3D Modeling and Energy Analysis of a Residential Building using BIM Tools. 2017, IRJET.
3. Sohail, M. and M. Qureshi, Energy-efficient buildings in pakistan. Science Vision, 2011. 16: p. 27-38.
4. Huang, L., et al., Carbon emission of global construction sector. Renewable and Sustainable Energy Reviews, 2017. 81.
5. Elnabawi, M., Building Information Modelling-Based Building Energy Modelling: Investigation of Interoperability and Simulation Results. Frontiers in Built Environment, 2020. 6: p. 193.
6. Mishra, K. and A. Goel, Energy Analysis of High Rise Building Integrated with BIM. Indian Journal of Science and Technology, 2019. 12(6): p. 1-10.
7. Sandberg, M., et al., Multidisciplinary optimization of life-cycle energy and cost using a BIM-based master model. Sustainability, 2019. 11(1): p. 286.
8. Kim, J.-U., et al., Development of A BIM-based maintenance decision-making framework for the optimization between energy efficiency and investment costs. Sustainability, 2018. 10(7): p. 2480.
9. Lu, Y., et al., Building Information Modeling (BIM) for green buildings: A critical review and future directions. Automation in Construction, 2017. 83: p. 134-148.
10. Kuo, H.-J., et al., A verification study for energy analysis of BIPV buildings with BIM. Energy and buildings, 2016. 130: p. 676-691.
11. Gardezi, S.S.S., N. Shafiq, and M.F.B. Khamidi, Prospects of Building Information Modeling (BIM) in Malaysian construction industry as conflict resolution tool. Journal of Energy Technologies and Policy, 2013. 3(11): p. 346-350.
12. Díaz-Vilariño, L., et al. As-Built BIM with shades modeling for energy analysis. in 2012 18th International Conference on Virtual Systems and Multimedia. 2012. IEEE.
13. Cho, C.-S., D. Chen, and S. Woo, Building information modeling (BIM)-Based design of energy efficient buildings. Journal of KIBIM, 2012. 2(1): p. 1-6.
14. Stumpf, A.L., H. Kim, and E.M. Jenicek, Early design energy analysis using building information modeling technology. 2011, Engineer Research and Development Center Champaign IL Construction.