Integrated BIM and Energy Tools with Building Certification System for Sustainable Building Design and Energy Certification

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Abstract— In recent times, the Architecture, Engineering and Construction (AEC) industry have raised awareness towards sustainable building, due to the rapid growth infrastructure development. Based on the experience, it was complicated and costly to determine the energy performance of building design, often caused postpone to the completion of the plan. Hence, Building Information Modelling (BIM) is discovered to improve the sustainability and economic saving of building with visualizing feature directly in the modelling environment. In this research, the BIM integrated with green building certification system and energy analysis tool to perform the energy analysis of building at the design stage. The integration of BIM and energy analysis tool with certification systems, enable the designer to understand energy used, carbon footprint implication of building design and address with the credit qualification of the green building certification. The tests and the results of the developed integrated system demonstrate that by using this system, the building performance can be optimized at the early design stage to fulfil the green building certification system requirements. Furthermore, the integrated system developed to facilitate the building stakeholders to explore more design alternatives and carry out real-time cost and effect information.

Keywords- *Building Certification System, Engineering and Construction (AEC), Building Information Modelling (BIM), real-time, Energy Certification.*

I. Introduction

Studies have proven that building is one of the sectors that have the largest user of energy. Energy efficiency in building design can appear in many ways and form. Therefore, many efforts that contribute from different engineering based it to continues find the excellent techniques and activities to decrease energy consumptions and environmental influences on building design. This research performs the energy analysis of a building at the conceptual stage using appropriate energy analysis tools and building information model for the compliance with building certification systems. With the current state of development of Building Information Modelling (BIM), the building information that includes its physical features, material selection, performance throughout its lifespan can represent in the single model design. Besides, there is no standard process of energy analysis for the developed BIM to comply with the green building certification system.

This research focuses on the energy efficiency category which mainly involves Indoor Environmental Quality (EQ), Sustainable Site Planning & Management (SM), Materials & Resources (MR). For example, carbon emission, electricity consumption, indoor air quality. This will have related through studies of building orientation, daylighting, natural ventilation, water harvesting and design new renewable energy modelling. As a result, this energy analysis tool will allow the engineer, architect and owners to refine and improve overall building efficiency at the conceptual stage and make a choice on alternative designs that will enable them to build a sustainable and energy efficient buildings [1].

BIM is one of the tools which used the intelligent 3D model-based process that provide a more efficient overall design. Energy analysis is highly recommended to participate as it will improvise the total design and it will comply with the Building Certification System to avoid double standard of design. However, lack of energy analysis of a green building design will result in a reduced level of energy saving in the different sector as well as create sizeable environmental impact.

1.2 Objectives of the Study

This research aims to integrate the Building Information Modeling (BIM) with Building Certification Systems to perform the energy analysis of a building at the conceptual stage using appropriate energy analysis tools. There are three objectives to be achieved in this proposal:

- Design and develop a Building Information Modeling (BIM) with emphasize of sustainable and energy efficient building design.
- Integrate the Building Information Modeling (BIM) along with energy analysis tools with the green building certification system.
- Evaluate the design information with the energy analysis tools to obtain credit qualification of the building based on certification.

1.3 Literature Review

A Green BIM Triangle Taxonomy had illustrated the critical reflection and comprehensive understanding upon the relationship between green building and BIM. It includes three dimensions, namely project phases, green attributes and BIM attributes that represents the analytical functions, project lifecycle perspectives and green buildings sustainability assessment. BIM provides sustainability measure opportunity for designers and engineers to integrate into the early design phase and tackle sustainability issues. That is the analysis of energy performance, carbon emission, lighting simulations, etc. that can be found in the analysis and simulation of the building. To keep in track and compare with the goals set in the design phase, BIM can be used to monitor the sustainable building performance during the operation phase. Which offers the advantages of energy, investment in capital and waste management in the retrofit green building project. The BIM lifecycle of green building as discussed shown in Figure 1. [2].

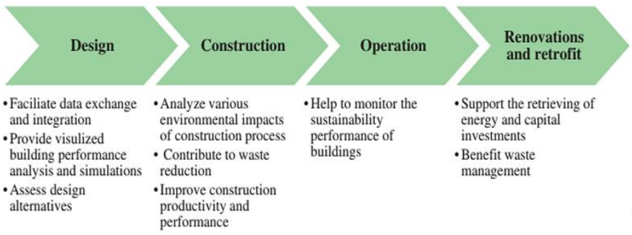


FIGURE 1. BIM-lifecycles of Green Building

Nevertheless, despite many conveniences provided by BIM, the ability to share information triggered cybersecurity. Due to the probability of unauthorized online access and copyright violation. Consequently, many BIM users experience a low return on investment due to the non-user-friendly interface [3]. BIM repository enables professionals to derive and share information through the construction delivery phases to produce efficient delivery of buildings. This study examines integrated project delivery (IPD) which may provide more sociological change, reciprocal risk share and rewards to reduce professional fragments. However, the gap has not yet determined about associated IPD and BIM [4].

The optimal design that provides minimum LCC throughout the life span of building to identify the most appropriate house components at the time of the design stage. When the building drawing created in Autodesk Revit, the entire components database will be transferred into Microsoft Excel to optimize the building design and used to compute LCC. The calculation of LCC enable the designers to verify the cost of components, components service life, salvage value, interest rate, embodied the energy and select the sustainable building components [5]. to perform transportation energy assessment needed the data from material quantities, type of vehicle and capacity as well as the travel distance. To identify the construction energy assessment will be required data of material quantities, power rating and productivities of equipment along with the information of work package from the built-in tool [6].

Many design schemes were tested to give the most energy-efficient building and discovered that the most significant energy conservation at the lowest cost was the fully optimal design scheme. Even though, BIM technology was proven to be capable in establishing high-precision simulation for building energy-conserving measures. The combination of economic and environmental analysis is the key to comprehensively justifying energy-saving benefits. BIM as an auxiliary tool requiring a high level of software expense investment and expert training. Alternatively, it may not be compatible with the partner because it is not accessible to use in construction professionals [7].

BIM enables users to visualize GUI data on energy consumption in the EOC. The step towards improving energy efficiency starts with the reinforcement of the geothermal heating system followed by the lighting, air-conditioning and photovoltaic system. However, the actual effect of 3D web browsers unable to be verified by applying huge energy conservation methods to the test bed simultaneously [8]. Automation in Construction about Green Building Assessment tool (GBAT) that implement the development in the building project to obtain green building certification by Industry Foundation Classes (IFC)-based framework integrate with BIM and highlight sustainable design improvement as shown in Figure 2. [9]

The international protocols (LEED, BREEAM and CESBA) as the tool to integrate with BIM in early stages enable better and more sustainable design according to the three concern key factors of environment, economic and social. For instance, IFC managed to interchange data from the BIM model to another professional software. Nonetheless, due to the limitation of IFC small property sets from calculating and store sustainability analysis. Therefore, the IFC standard is indeed to be expanded to handle all the required data by sustainability rating for the project [10].

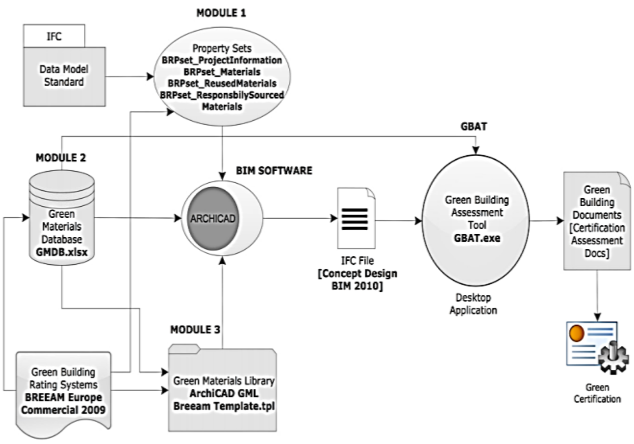


FIGURE 2. Proposed Integrated BIM-Sustainable Information Model

Creative Construction Conference to propose a framework for the integration of BIM and WMS for Green Building Certification. BIM module to extract the project database of location based on longitude and latitude, the area of a site, building to synchronize the information between UI and BIM. Whereas, WMS to get the building map, traffic, local services from Geographic Information System (GIS) server of the various provider such as (Google, Yahoo etc.) [11].

II. PROPOSED METHODOLOGY

Figure 3. shows the block diagram of the proposed design which consist of two parts: A and B. Initially, by looking to part A, a 2D commercial building drawing from Autodesk AutoCAD will be integrating with DIALux to obtain the illuminance level result and lighting design layout for every single room. Subsequently, Autodesk AutoCAD the content of 2D commercial building drawing will integrate with Revit to obtain building modelling information. By achieving the target objectives, the process is then carried on to combine with Autodesk Insight which can to enhance the building modelling by different scenarios and obtain building performance analysis. Apart from that, Autodesk Insight can be operated as standalone simulation service or integrate with Autodesk Green Building Studio (GBS) to optimize the building energy efficiency report that facilitates with green building certification system (LEED).

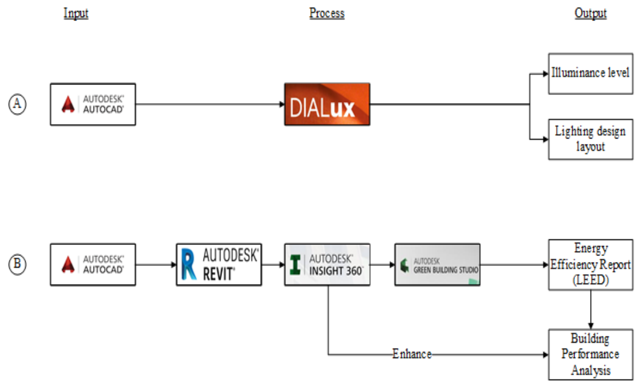


FIGURE 3. Block Diagram of Proposed Methodology

The primary objective is to design and develop a BIM model to optimize energy efficiency with the integration of green building certification in a computerized manner. The block diagram as can be seen in Figure 4. illustrates, this automated system will be integrating will different software and cloud computing service. The sequential flow of proposed system involves implementing through 5 subsequent phases that shown in Figure 4.

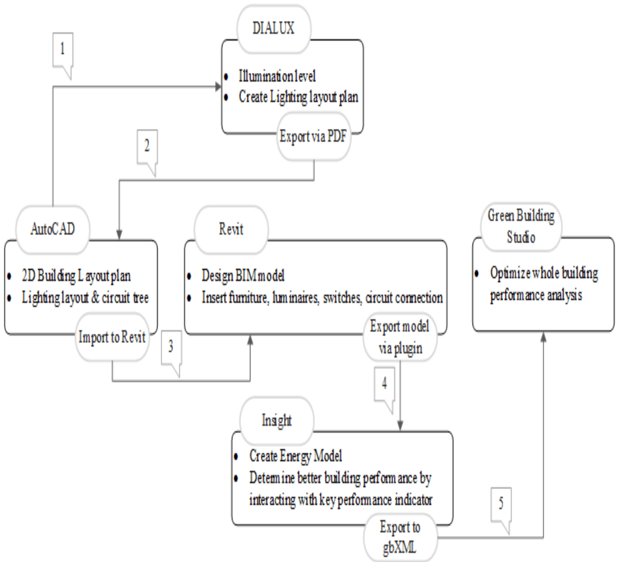


FIGURE 4. Block Diagram of BIM integration system

Phase 1 consists of the integration between two software; they are Autodesk AutoCAD and DIALux. A 2D building layout plan from AutoCAD will be imported as a .dwg file to DIALux in order to have an accurate dimension of room to create the lighting layout plan. For instance, the main keys of great lighting layout are Color Rendering Index (CRI), colour temperature, illumination level, lighting distribution analysis.

Phase 2 focuses on export the design of lighting layout plan to AutoCAD. Once the lighting plan developed, first to justify whether it reaches the desired result and export as a pdf file to AutoCAD in order to draw the wiring circuit tree along with the luminaire placement in the initial 2D building layout plan.

Phase 3 concentrates on developing a 3D building model from imported initial 2D building layout plan that includes lighting and circuit tree plan to Autodesk Revit. The dimensions of the 3D model will draw accordingly to the imported 2D building design plan. Furthermore, the implemented 3D model has the capability to store newly imported families such as furniture, luminaires, switches into a BIM tool with certified green materials that commonly used in commercial building. This process including modifying and duplicating existing family to add an essential feature to the model such as the colour of the wall, the area of walls, curtain walls, doors, roof and so forth. Also, the circuit tree from AutoCAD in phase 2 will set a reference to help in creating wiring connection in between the luminaires and switches as similar as the circuit tree plan in 2D CAD drawing.

Phase 4 describes the designing energy analysis of a building that happens by the integration in between implemented 3D model with an intelligent automatic simulation model, Autodesk Insight. It is an energy analysis tool that can be linked to Revit in phase 3 as a plug-in tool to determine the entire energy of the building, includes cooling, daylighting, heating, solar radiation, and so on. The energy model will create with the respect of the 3D model from phase 3. Before, generating the energy model, the designer will be required to set the operating schedule of the building along with specifying the address of the location to look for the nearest weather station and initiate an accurate building performance analysis. Insight has visualized potential to interact with the key performance indicator which can be considered as a design scenario in overall changes to achieve high performance and sustainable building design at the conceptual stage of infrastructure work.

Phase 5 includes the simulation of whole building performance with the respect of green building certification, cost estimating analysis. The integration between Autodesk Insight and GBS based on the data of key performance changes made in design scenario phase 4, will be exported to GBS in a gbXML file. GBS is a cloud-based energy analysis tool that will be able to optimize energy efficiency and interoperability potential with the other tool. GBS can use as an independent energy analysis tool or the entire building energy analysis tool for Autodesk Revit. The analysis in GBS includes utility cost for energy, lifecycle and works beyond the capability of performing whole building energy analysis that utilizes DOE-2 simulation tool. For instance, LEED daylight, water efficiency, carbon emission data, natural ventilation potential, photovoltaic potential towards developing a green, sustainable building. Full benefit from daylighting controls throughout the proposed building model towards the sustainable aspect, it is encouraging to obtain more than 75% in the score of LEED daylight. The data information and charts in GBS helps the designer to visualize and understand the use, cost of energy also it gives the opportunity for the designer to revise energy settings and parameters in the 3D model generated in phase 3, to reduce the impact of energy use by comparing simulation result.

2.1 Lighting Simulation and Analysis

The proposed commercial building consists of 4 departments such as bank, clinic, salon and supermarket. There are two different height of walls in the proposed commercial building. For instance, the wall height of the supermarket part is 5 meters; the wall height of bank, clinic and salon is 3 meters. Figure 5. illustrates the procedure of DIALux simulation and analysis. The proposed 2D building layout from AutoCAD import to DIALux. First, according to the dimension of the proposed building layout, the room will be created. Next, the doors, windows and furniture will be inserted accordingly, to produce an accurate illuminance level analysis after adding luminaire. Then, the position of the luminaire including height, spacing will be specified to carry out simulation and analysis and compare with standard recommended illuminance level.

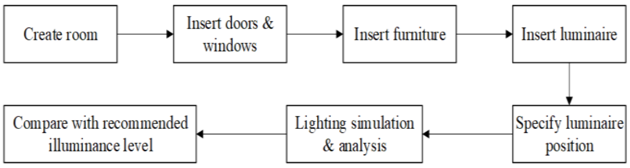
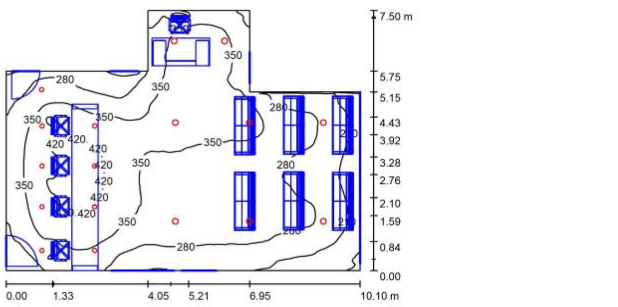


FIGURE 5. Block Diagram for lighting simulation and analysis

2.2 Bank Teller Counter & Waiting Area

The blue colour blocks denote the furniture, windows, and doors. There are two kinds of LED downlights have been used for lighting design as shown in Figure 6. The total amount of nine 14W recessed LED downlights that placed at the waiting area to give the average of 280 to 350lux and create a decent, comfortable and welcoming environment. On the other hand, two 25W ceiling-mounted LED downlights design to be mounted on the bank teller counter to help the customer pay essential attention to the document at the front desk by adequate light distribution. The range of average to maximum illuminance shows 318lux, which fulfil the general working interior lighting requirement of Malaysia standard as the range in between 300 to 400lux.

BANK TELLER COUNTER & WAITING AREA / Single Sheet Output



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.80 — Values in Lux, Scale 1:97

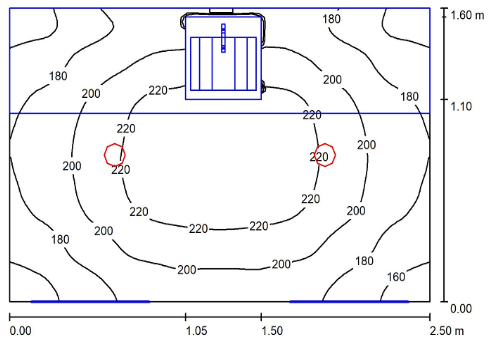
Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	318	107	451	0.337
Floor	20	212	17	349	0.082
Ceiling	80	72	37	129	0.513
Walls (9)	50	158	29	444	/

FIGURE 6. Bank Teller Counter & Waiting Area Room Summary

2.3 Bank Pantry

The lighting layout as shown in Figure 7 used one type of 14W recessed LED downlight. The luminaires are mounted horizontally in equal space to distribution an average of 197lux. Based on the recommended average illuminance levels for the kitchen by Malaysia Standard is 150 to 300lux. Obviously can be seen the simulated average illuminance address the recommended lighting requirement and this applies to the rest of the pantry in the proposed commercial building. Not to mention, such luminaire has colour temperature as 5000k that gives significant contrast among colour especially for the kitchen as well above 80 of CRI. CRI clarifies the impact of a light source on the colour appearance of an object. Henceforth, the higher the colour temperature and CRI of a luminaire provide a better impression of an item.

BANK PANTRY / Single Sheet Output



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.80 — Values in Lux, Scale 1:21

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	197	148	234	0.752
Floor	20	80	1.39	144	0.017
Ceiling	70	73	55	81	0.752
Walls (4)	50	128	2.09	324	/

FIGURE 7. Bank Pantry Room Summary

2.4 Bank ATM Area

Similarly, the room summary of ATM where blue blocks represent furniture, windows and door. There are two types of luminaires involved in designing the lighting layout for the ATM area. Both recessed LED downlight has the specification of 14W and 12.8W respectively. The average illuminance level as 246 lux, the reason why it is higher than usual, to compromise with the safety of ATM user, not to obstruct visualization where potential muggers lie in, their faces can be seen clearly by the closed-circuit television (CCTV) and help in the criminal inspection.

2.5 Clinic Waiting Area

According to the lighting requirement by the Department of Occupational Safety and Health, the illuminance should be 200lux for clinic waiting area.

III. WORKING PRINCIPLE

The model developed in this paper concentrates on the automation tool of building energy efficiency analysis with BIM module. Figure 8. illustrates a system flow of the integration process that identifies the procedures apply to the design plan in BIM while considering every single related criterion and particular.

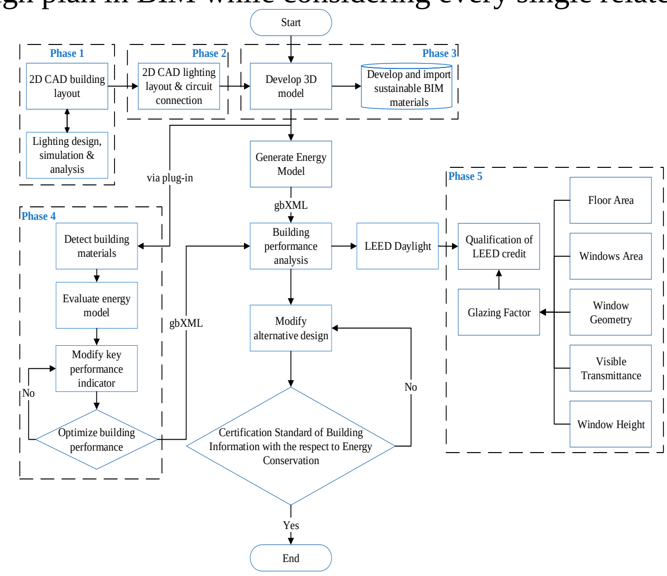


FIGURE 8. System flowchart of the integration process

IV. SIMULATION RESULTS

In GBS, to ensure the proposed model to achieve full advantage from daylight control, it is necessary to score more than 75% of glazing factor from LEED Daylight as shown in Figure 9, the simulation result is 79.9%. When the model fulfils qualification of LEED Daylight credit, it reduces the carbon emission, creates the more photovoltaic potential that determines by all the exterior surface like wall, roof and windows to generate electricity. The analysis result of photovoltaic potential can refer to Figure 10.

LEED Daylight (more details)

Percentage of building area with glazing factor over 2%: **79.9% - Qualifies for LEED Credit**

LEED Water Efficiency (more details)

	L / yr	$ / yr
Indoor:	2,380,486	$3,460
Outdoor:	1,063,385	$730
Total	**3,443,871**	**$4,191**

FIGURE 9. LEED Daylight Qualification

Photovoltaic Potential (more details)

Annual Energy Savings:	341,845 kWh
Total Installed Panel Cost:	$1,605,211
Nominal Rated Power:	201 kW
Total Panel Area:	1,453 m²
Maximum Payback Period:	35 years @ $0.09 / kWh

Wind Energy Potential

Annual Electric Generation:	119 kWh

FIGURE 10. Photovoltaic Potential

The estimated energy, cost and carbon emission demonstrate in Figure 11. The result was evaluated by using average utility rates in the United States, as can be seen, the currency written in US Dollar. The annual and lifecycle energy here refers to the consumption of electric and gas. Whereas, the carbon emission refers to the onsite fuel consumption and the electricity fuels sources in Malaysia.

Energy, Carbon and Cost Summary	
Annual Energy Cost	$39,182
Lifecycle Cost	$533,656
Annual CO_2 Emissions	
Electric	0.0 Mg
Onsite Fuel	1.9 Mg
Large SUV Equivalent	0.2 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	883 MJ / m² / year
Electric	414,294 kWh
Fuel	37,635 MJ
Annual Peak Demand	91.8 kW
Lifecycle Energy	
Electric	12,428,823 kW
Fuel	1,129,050 MJ

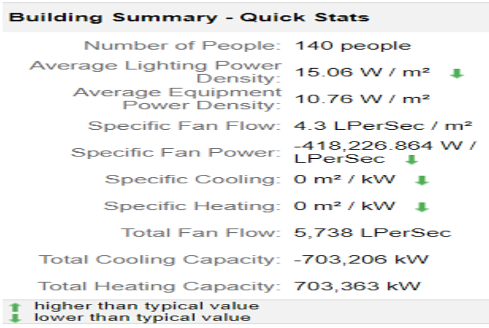
FIGURE 11. Cost, Energy and Carbon Emission Analysis

V. TESTING OF PROPOSED DESIGN

5.1 Performance Test (Test 1)

The specification of the proposed 3D model involves the entire floor area of 1,732 m², all the colour of the wall set as white while the area of windows is 1,383.9 m². The following Figure 12. shown as the building summary analyze by using GBS of the developed BIM model. It shows the commercial building may occupy 140 people at a time, the average lighting power density as 15.06 W/m², average equipment power density as 10.76 W/m². For HVAC categories in the model, the specific fan flow as 4.3 L/s/m², the specific fan power as -418,226.864W/L/s whereas the total fan flow, cooling and heating capacity as

5,738 L/s, -703,206 kW and 703,363 kW respectively. There is four specific analysis of the room indicate lower than typical value by an arrow pointing down.



Building Summary - Quick Stats	
Number of People:	140 people
Average Lighting Power Density:	15.06 W / m²
Average Equipment Power Density:	10.76 W / m²
Specific Fan Flow:	4.3 LPerSec / m²
Specific Fan Power:	-418,226.864 W / LPerSec
Specific Cooling:	0 m² / kW
Specific Heating:	0 m² / kW
Total Fan Flow:	5,738 LPerSec
Total Cooling Capacity:	-703,206 kW
Total Heating Capacity:	703,363 kW

higher than typical value
lower than typical value

FIGURE 12. Building Summary of the developed model

5.2 Area of the Glass (Test 2)

The model floor area remains at 1,732 m², and the colour of the wall remain white. The area of glass will be varied and carry out the tabulate result for cost, energy and green building certification analysis. The annual cost of electric as shown in Figure 13 climbed gradually in the first two glass area test and increased sharply at third glass area test, whilst slightly dropped in the fourth test and upsurge in the fifth test. Figure 14 indicates the annual electric and fuel energy analysis, for annual electric energy, it increases gradually from first to the third test and decreased slightly in the fourth test finally the fifth test reach the highest electric consumption; for annual fuel energy, it remains constant reading until the last test grew a little in the last test.

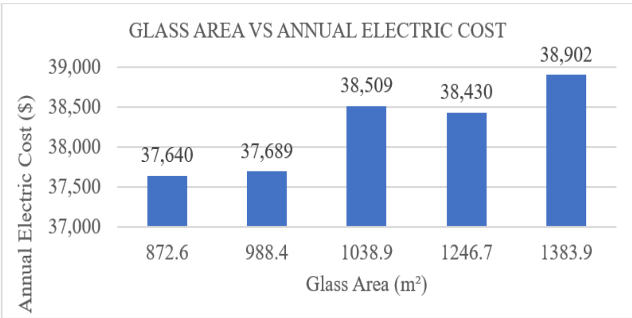


FIGURE 13. Bar chart of Annual Electric Cost for Testing 2

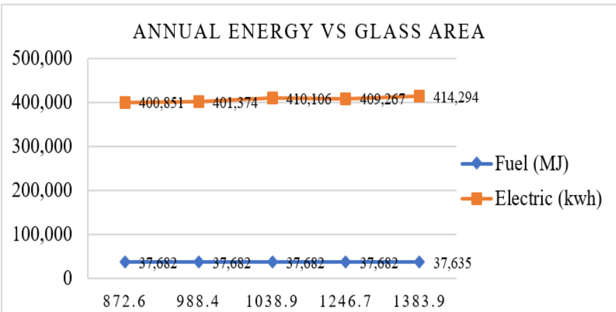


FIGURE 14. Line chart of Annual Energy for Testing 2

Figure 15. illustrates the analysis of electric and fuel lifecycle energy. For electric lifecycle energy, the result goes up minimally from the first to the third test, reduce steadily in the fourth test and stepped up in the last test. Similarly works as the same behaviour of the glazing factor in Figure 17. Figure 16 is the annual electric end-use analysis for HVAC, lights and Other. For HVAC the action of the graph is similar as glazing factor, while lights and other remains constant in the first and second test, went down moderately in third test and last test while picking up steadily in the fourth test.

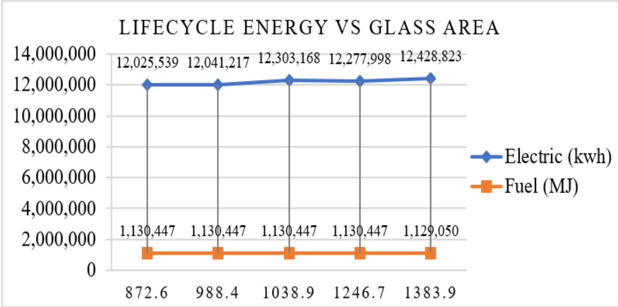


FIGURE 15. Line chart of Lifecycle Energy for Testing 2

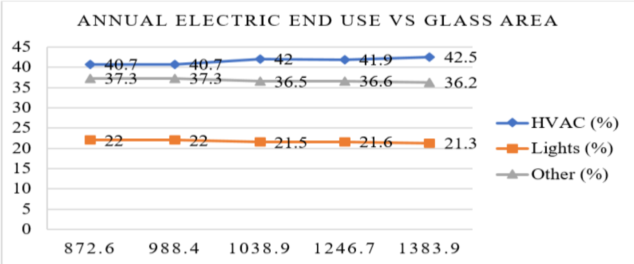


FIGURE 16. Line chart of Annual Electric End Use for Testing 2

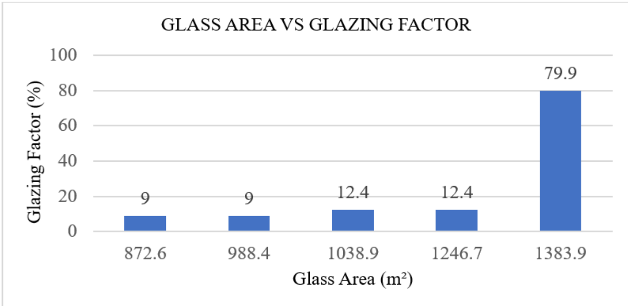


FIGURE 17. Bar chart of Glass Area for Testing 2

5.3 The colour of the wall (Test 3)

The model floor area remains at 1,732 m², the area of the glass will be 1383.9 m². The colour of the wall varied from grey, white, black, yellow and brick to obtain the tabulate result for cost, energy and green building certification analysis. The glass area remains at1383.9 m² for all the test for the colour of the wall. Default colour refers to grey; the remaining are white, black, yellow and brick colour. The results of annual fuel cost, energy, green building certification analysis remain the same for all the test. The only changes in the collected numerical result are annual electric cost by white wall colour that is $5 more than the rest.

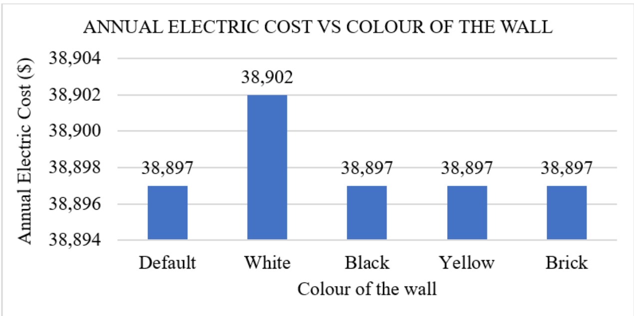


FIGURE 18. Bar chart of Annual Electric Cost for Testing 3

5.4 Area of the glass & colour of the wall (Test 4)

The model floor area remains at 1,732 m², the area of the glass will be 872.6 m² and 1246.7 m². The colour of the wall varied from grey, white, black, yellow and brick to obtain the tabulate result for cost, energy and green building certification analysis. Unfortunately, two selected glass area along with five different colour to construct the test shown that none of the tests does meet the minimum requirement of glazing factor to obtained the qualification of LEED credit. The results show all the analysis collected by two different glass area remains the same except the total annual energy cost of white colour for both tests. Figure 19. shows the behaviour of the annual electric cost.

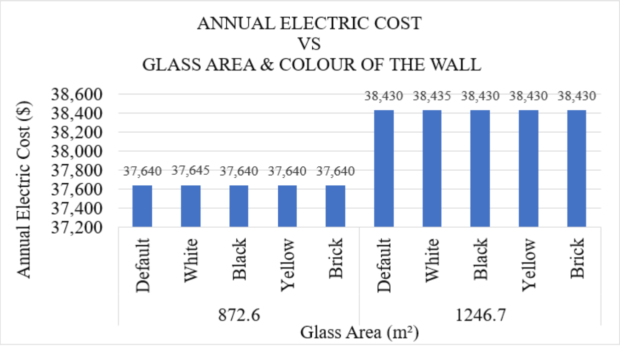


FIGURE 19. Bar chart of annual electric cost for Test 4

5.5 Customize the Design Scenario Test

The model floor area remains at 1,732 m², the area of the glass will be 1383.9m², the colour of the wall will be white. However, the building performance will be varied to obtain the tabulate result for cost, energy and green building certification analysis.

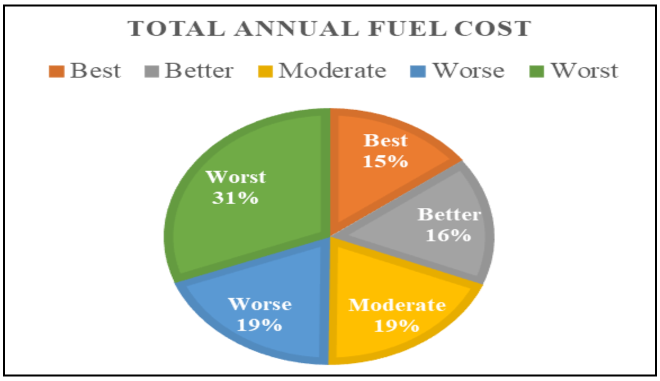


FIGURE 20. Pie chart of Total Annual Electric Cost for Test 5

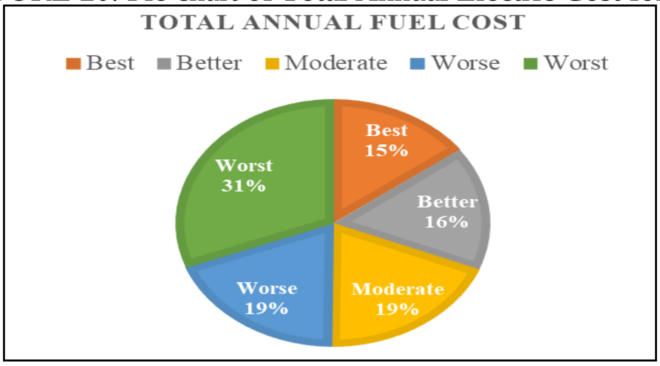


FIGURE 21. Pie chart of Total Annual Fuel Cost for Test 5

VI. CONCLUSION

This research intends to integrate the BIM with Building Certification System to perform the energy analysis of a building at the conceptual stage using appropriate energy analysis tools. The developed automated system has overcome the trouble of high initial cost of construction this may cause due to in compliance with green building certification, which unable to predict the demand of carbon emission, electricity consumption and cost; as well as unable to optimise actual energy efficiency by applying different scenarios in one model. Additionally, based on past experiences, it would be very complicated and costly to identify the energy efficiency of the building, often cause the postpone to the completion of construction.

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