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3D Modeling and Energy Analysis of a Residential Building using BIM Tools

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ABSTRACT- Energy analysis is becoming an important factor to be considered in the AEC industry these days because of the worsening global warming and energy crisis. The energy analysis needs to be amalgamated into the design phase of the building with respect to the increased regulations required all over the world. Forecasting the energy usage of the building and using a suitable energy conserving measure and design for construction is a need of the hour. The paper is based on the Autodesk BIM capabilities to perform an Energy analysis of a G+9 Residential building. The paper seeks to find and help integrate the use of BIM energy analysis results in the predicting the energy consumption of the building. This will further help in keeping track and study the energy consumption of the building in the future maintenance. Any major variations, steps to saving the energy expenses or avoiding wastage of energy can be done with help of this results. For this purpose the Autodesk Revit Software and a BIM software, i.e. Green Building Studio, which is a cloud based energy analysis program are used.

Keywords: **Building Information Modeling(BIM), Autodesk Revit, Autodesk Green Building Studio, Energy analysis.**

1 INTRODUCTION

Building Information Modelling consist of a digital representation of physical and functional characteristics of a building. It serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward". The models created are approximately close to the real building. The closer the model is to reality, greater the chance to create a high performing building.

1.1 Energy/ Sustainability Analysis

A certain amount of energy is required for a building to operate, maintain user comfort and for functionality. Energy balance is necessary for the estimation of needed energy demand. The energy needed is due to energy losses caused by transmission and ventilation losses from the building envelop. These losses can be compensated fully or partially with help of appliances or by solar energy through the openings. Use of natural energy as much as possible will lead to less amount of fuel consumption of the building. Extra amount of energy input is required for lighting, ventilation and for the operation of building systems. When proper energy gains are attained and deducted from the energy losses of the building determine the overall energy demand of the building. Proper understanding of need of energy analysis will help creating a proper energy model.
The main reasons for energy modeling are usually

- Compliance to code and/or project energy use estimation.
- Early stage model, providing assistance during design, construction and maintenance phase.
- Progress models during construction ensures that the project remains on track for energy or emission targets and also for maintenance.
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1.2 BIM and Energy/ Sustainability Analysis

BIM provides us with a proper sustainable design because it helps to iteratively test, analyze and also improve design of building. This is called Building Performance Analysis (BPA). BIM energy analysis tools helps in forecasting the thermal comfort of the occupant and the energy performance of a building. The analysis helps to know how a building will operate at certain criteria and a comparison can be done for different design alternatives. The data input required for the energy analysis of the structure are:

- The building geometry which includes the layout and configuration of the space (surfaces and volumes),
- The orientation of the building.
- Information about the materials used and their thermal properties of construction elements.
- Functional use of the building to be studied and analyzed.
- Schedules for lighting, occupants, and equipment,
- Heating, ventilating, and air conditioning (HVAC) system type
- The current utility rates and weather data of the area the structure is situated in.

1.3 Autodesk Building Performance Analysis

Autodesk's core BIM tools with BPA capabilities are: Revit, Vasari, and Green Building Studio. There are two main category of these feature tool:

- Whole building energy analysis: This is based on building type, geometry, climate, envelope properties, HVAC and lighting. It helps in calculating the energy consumption such as fuel and electricity. The building as a whole system is taken into account with all the elements working interdependently
- Performance based Design Studies: This type is for design studies such as sun path, daylight, wind, airflow. Revit and Green Building Studio help and focus on the performance analysis.

1.4 Revit

Revit is a used throughout the 3D modelling process and it is a full-featured building information modeling platform. "Building Elements" like walls, roofs, windows, and floors to create 3D models are used in the Autodesk Revit software. Conceptual massing capabilities is also an feature available in Revit which uses basic shapes to model building form and orientation earlier in the design process. Revit also has tools for MEP design and structural design apart from the Architectural modelling. It is the modelling end of the Energy simulation workflow. Hence, it is very popular in the AEC industry for design purposes.

1.5 Green Building Studio

Green Building Studio is a web-based simulation engine for whole building energy analysis. It is based on the DOE-2 simulation engine and powers the BIM Based Energy/Sustainability.
Whole building energy analysis tools across Autodesk products: - Revit and Vasari. DOE 2 is a back end to GBS which is more like a user interface that displays the generated data in a readable format. It can perform analysis on any gbXML file, therefore any software capable of gbXML export can also work with GBS. GBS does not have 3D modeling capabilities. It is solely dependent on external sourced data. Autodesk whole building analysis workflow is shown in the diagram. GBS requires an Autodesk subscription for a full exploration of its capabilities, although it can still work with just an Autodesk registration but certain parameters in the software cannot be edited. Since it is cloud based, it cannot be installed on a host machine. The advantage is that the results can be viewed anywhere with an internet connection.

2 REVIEW OF LITERATURE

The definitions available for BIM in the literature, so as to understand clearly the real agenda of BIM is necessary. Consideration is also given to the natural environment, user environment and owner satisfaction throughout the lifecycle within this definition. BIM helps providing value judgments required for creating a more sustainable infrastructure that will comply with the needs of the owners and occupants. BIM seeks to integrate processes throughout the entire lifecycle of a construction project as a lifecycle evaluation concept. The information provided by BIM analysis should be consistent and such that it can be used throughout the lifecycle of the project. BIM uses the method of collaborating the stakeholders in project using ICT to exchange valuable information throughout the lifecycle.
Building Energy Modeling (BEM), which is another feature of Building Information Modeling (BIM), integrates energy analysis into the design, construction, and operation and maintenance of buildings. There are various software's available for the evaluation of the structure in various phases of the building lifecycle. Twelve BEM tools initially were evaluated using four criteria: interoperability, usability, available inputs, and available outputs. Three BEM tools were selected based on the initial evaluation. BEM tools selected helped in finding out the energy usage, daylighting performance, and natural ventilation for two academic buildings (LEED-certified and non-LEED-certified).

3 METHODOLOGY

For the purpose of the evaluation and study of Autodesk Revit and GBS a case study of a residential building was used. The case study involved actual Residential building (G+9) project at Vakola, Santa Cruz, Mumbai, Maharashtra, India. This involved using Building models created in Revit for analysis within Revit and export to GBS for further analysis.
The first stage in Energy simulation is to define the energy target. The proposed target was to;

- Collect the drawings and information about the building to be studied.
- Study the drawings and create a 3D model using the Autodesk Revit software.

- Export it to the gbXML format for further analysis in GBS software.
- Analyse and run results in the Green Building Studio software over the cloud.
- Estimating energy use of the building.

A 3D model is created in the Autodesk Revit software using the Floor plan available of the building. Then Room tags are given to the rooms, which are created using the Revit "Room" Tool. It is important to create Rooms which will help while exporting the file to gbXML format. While exporting to gbXML select the type of building it is, the location of the project, in Building Element select Rooms or Spaces (if conceptual Energy Mass model is created), if the thermal properties are to be considered select that and then export the file.

Then Sign In, in the Autodesk Green Building Studio, which is a cloud software. Create a Project in the "My Project" segment. Update the Project details about the location, the type of building, the use of building type in the Schedule section, if the project is actual ongoing project or just study for academic purpose. The location of project will help in determining the nearest Weather Station & weather details of the area of project, helping in the analysis. Update the Utility rates for Electricity Consumption and for Fuel Consumption. You can also update details about the Project Members involved. Now update the gbXML file in the project created for base run and achieving results. The file will upload and display results based on the input given. The result showcases the consumption of electricity, fuel and its cost. The Charts further display in detail the annually energy consumed, CO2 emission, lifecycle cost, etc. The values obtained are as close to actual values as much correct details are given while creating the model. Some values are default set in the software.

There is also option for Design Alternative option to the existing model where we can modify the HVAC details, the Roof construction details, the Glazing of Walls, the type of Lighting used, to know options for creating a more energy efficient building.

Figure No.1: Model-3D created in the Autodesk Revit Software.

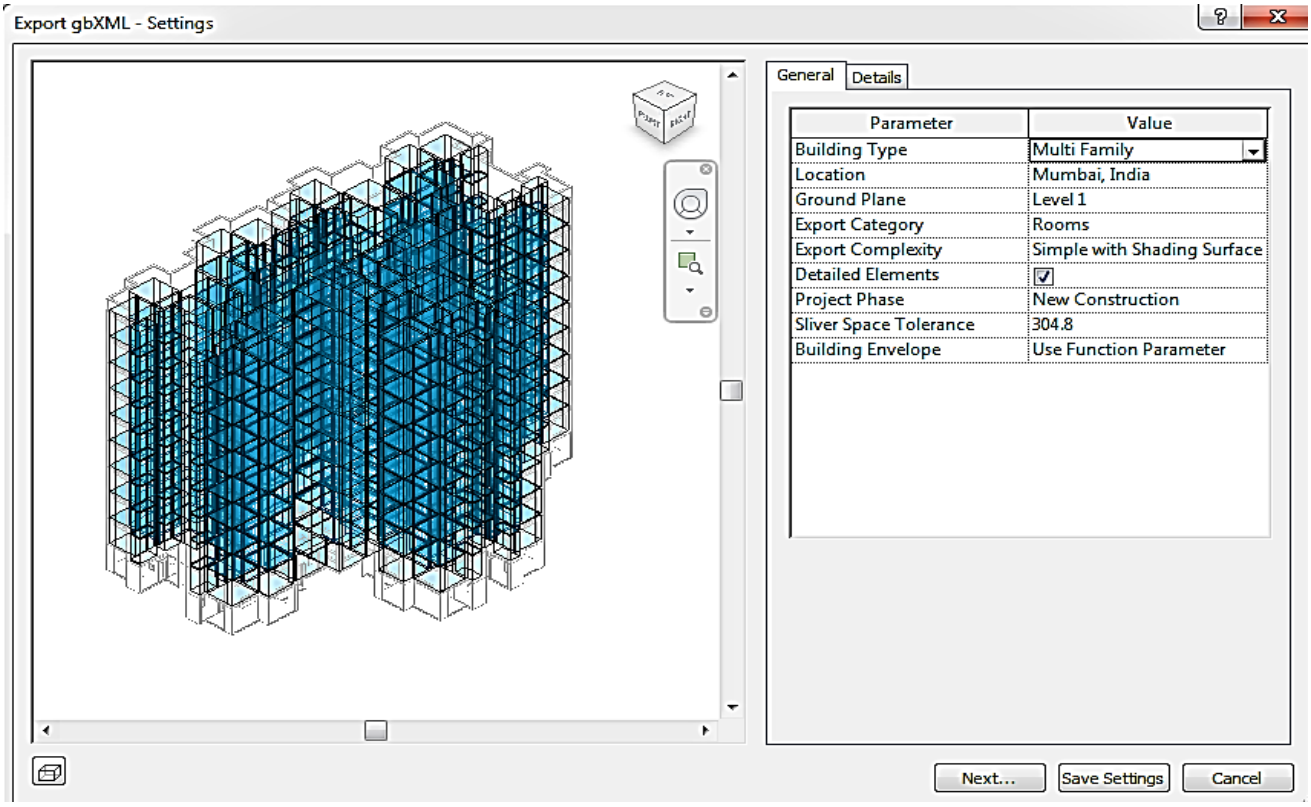

Figure No. 2: Exporting the file to gbXML format in Autodesk Revit

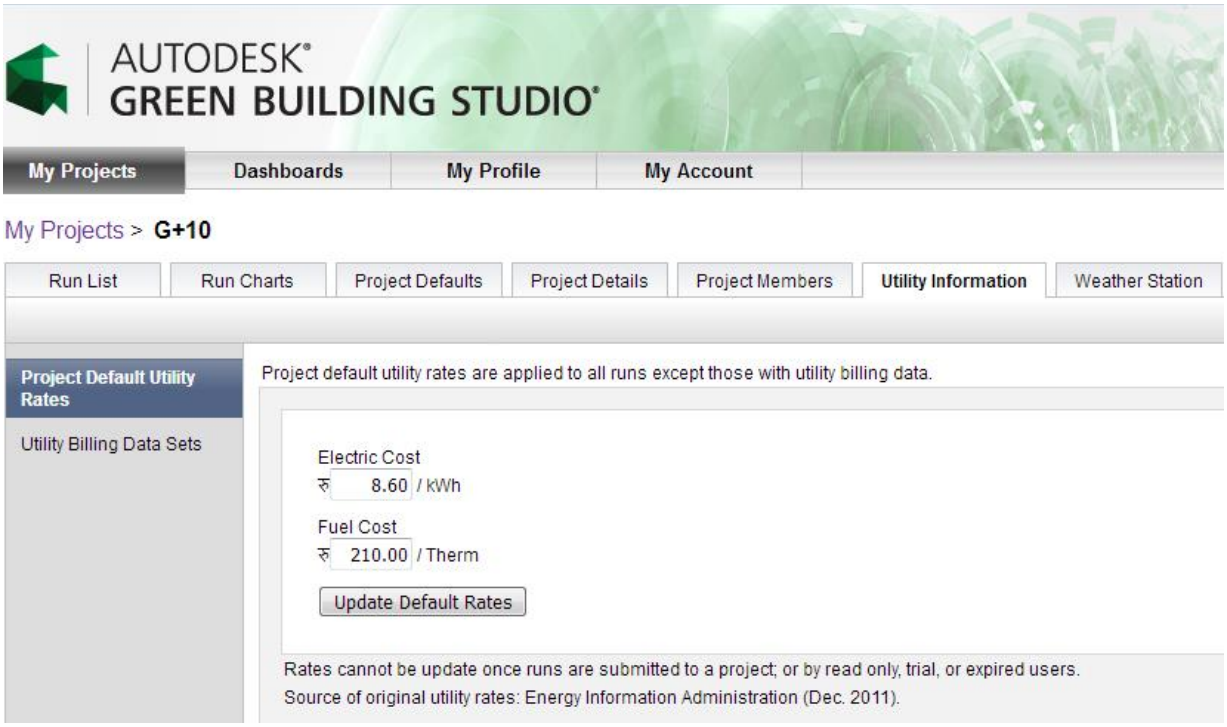

Figure No. 3: Updating the Utility Rates in Green Building Studio software

Run List | Run Charts | Project Defaults | **Project Details** | Project Members | Utility Information

Name	G+9 Residential Building
Building Type [1]	Multi Family
Schedule [1]	Default
Project Type [2]	○ Actual Project: A new or existing building project ◉ Test Project: For Learning or demonstration only
Address [3]	Station Road
City [3]	Mumbai
State/Province [3]	
Postal Code [3]	400055
Country [3]	India
Time Zone [3]	India Standard Time
Currency [3]	Indian Rupee (INR)

Figure No. 4: Updating project details in the Green Building Studio software

4 RESULTS

These are the results achieved from the energy analysis done over the cloud in the Green Building Studio software. The results obtained are approximate as all the details about materials and aspects were not exactly available.

Actions ▾ Display Options ▾

Name	Date	User Name	Floor Area (m²)	Energy Use Intensity (MJ/m²/year)	Electric Cost (/kWh)	Fuel Cost (/MJ)	Total Annual Cost [1] Electric	Fuel	Energy	Total Annual Energy [1] Electric (kWh)	Fuel (MJ)	Carbon Emissions (Mg)	Compare	Potential Energy Savings
Project Default Utility Rates													Weather Data: GBS_06M12_12_103135	
Project Default Utility Rates	–	–	–	–	₹8.60	₹1.99	–	–	–	–	–	–		
Base Run														
Projectwithouthvac.xml	6/28/2017 3:21 PM	asmishivsharan	4,337	567.5	₹8.60	₹1.99	₹5,055,453	₹686,990	₹5,742,444	587,843	345,155	192.7		

Floor Area (m²)	Energy Use Intensity (MJ/m²/year)	Electric Cost (/kWh)	Fuel Cost (/MJ)	Total Annual Cost [1] Electric	Fuel	Energy	Total Annual Energy [1] Electric (kWh)	Fuel (MJ)	Carbon Emissions (Mg)
									Weather Data: GB
--	--	₹8.60	₹1.99	--	--	--	--	--	--
4,337	567.5	₹8.60	₹1.99	₹5,055,453	₹686,990	₹5,742,444	587,843	345,155	192.7

Figure No. 5: GBS simulated Base Run results in the Green Building Studio software

1 Base Run

Energy, Carbon and Cost Summary	
Annual Energy Cost	₹5,742,589
Lifecycle Cost	₹78,214,057
Annual CO_2 Emissions	
Electric	175.4 Mg
Onsite Fuel	17.2 Mg
Large SUV Equivalent	19.3 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	568 MJ / m² / year
Electric	587,843 kWh
Fuel	345,155 MJ
Annual Peak Demand	105.9 kW
Lifecycle Energy	
Electric	17,635,302 kW
Fuel	10,354,662 MJ

Figure No. 6: Energy, Carbon & Cost Summary

Carbon Footprint

Base Run Carbon Neutral Potential	
Annual CO_2 Emissions	Mg
1 Base Run	192.7
Onsite Renewable Potential	-3.8
Natural Ventilation Potential	-9.9
Onsite Biofuel Use	-17.2
Net CO_2 Emissions	**161.7**
Net Large SUV Equivalent: 16.2 SUVs / Year	
Assumptions	

Electric Power Plant Sources in Your Region	
Fossil	61 %
Nuclear	35 %
Hydroelectric	3 %
Renewable	1 %
Other	0 %

Figure No. 7: Base Run Carbon Neutral Potential & Source of Electric supply in vicinity

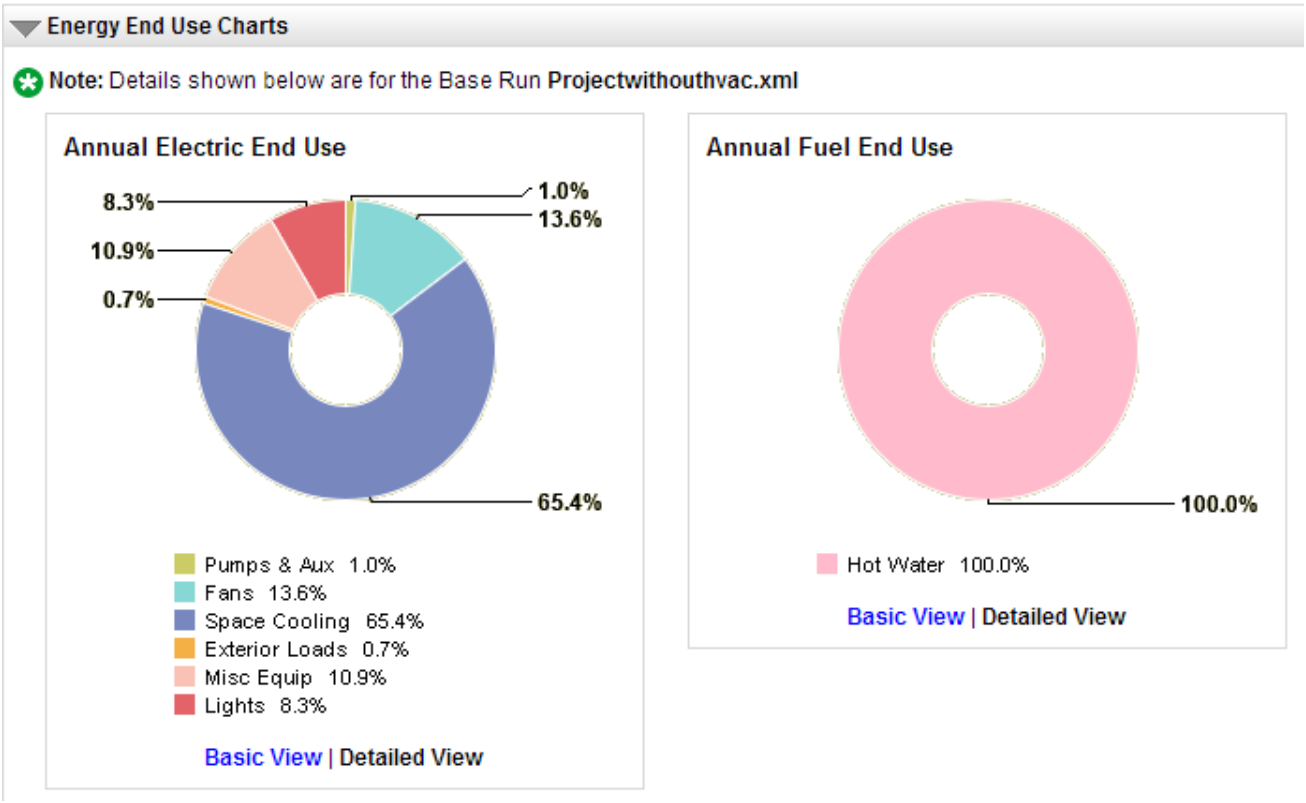

Figure No. 8: Energy End Use Charts

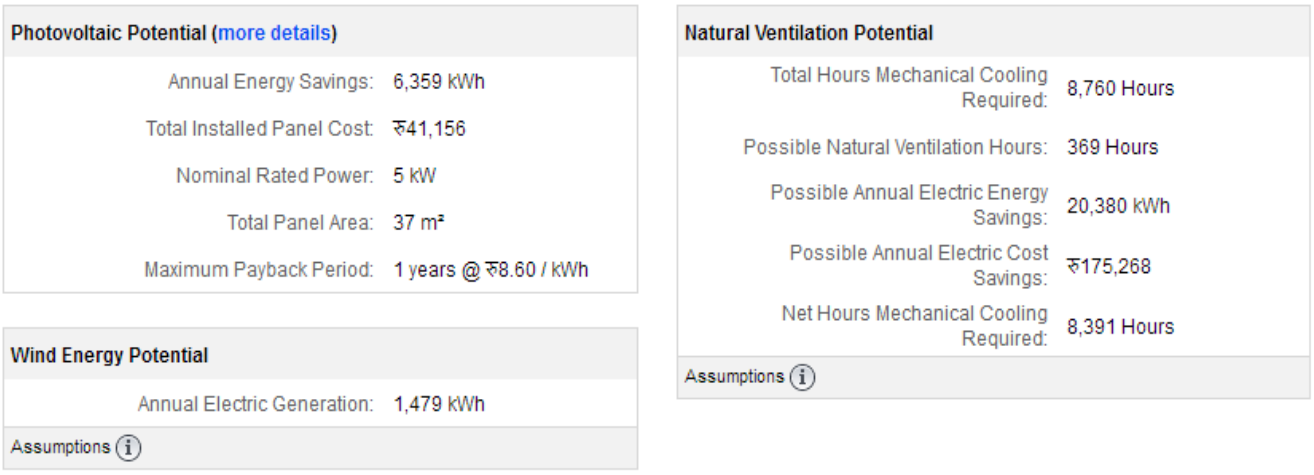

Figure No. 9: Photovoltaic, Wind Energy and Natural Ventilation Potential

5 CONCLUSION

Increase in the number of analysis tools is a sign to the increasing importance of sustainable design in architecture and the need to optimize building performance. The BIM-based design and documentation system is ideally suited for delivering the kind of information that can be used to improve design and building performance. Much of the data needed for supporting green design is captured naturally during the design process and is extracted from the building information model as needed. Revit Architecture facilitates the very complex process of sustainable design like daylighting and solar access, and automates the drudgery of activities like material takeoffs- all the while capturing and coordinating information in the documentation set. Linking this product to Revit Architecture make this technology far more accessible

than before, giving architects easy access to tools that provide quick feedback on green design alternatives.

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