BIM Based Building Performance Analysis Of A Green Office Building

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Abstract— Over the past few years, Green and Sustainable Buildings have gained a lot of prominence owing to the growing environmental concerns. Buildings have acquired a significant share in the overall energy usage and have also become a major source of CO_2 emissions throughout its lifecycle. Construction of Green Buildings by incorporating various sustainable design parameters may be a tedious process, but integrating Building Information Modeling (BIM) in the design can make the procedure much simpler. In this study, the building performance of a Green Office Building is assessed in terms of sustainability using BIM. Similarly, performance analysis is carried out for a conventional building to explore the ecological advantages of erecting a Green Building. The analysis gave about 15% energy savings, 22.3% water usage savings and 21% carbon reductions in the Green Building compared to the Conventional Building. Also, an alternative for the Green Building Design is evaluated which showed 4.7% Energy Cost Savings and about 38.6% Reduction in CO_2 emissions compared to the original design. So,with this method, different alternatives for the design are easily generated in the conceptual phase itself and therefore, decisions regarding the design are made easily. But this technique generates results which mainly focuses on the operation phase of a building with least attention given to material production and transportation stage. Also, there are chances of errors due to file transfer in different formats while carrying out the analysis in BIM.

Index Terms— Building Information Modeling, Conventional Building, Design Alternative, Green Building, Green Building Studio, Performance Analysis, Revit.

1. INTRODUCTION

Green buildings are considered as environment favorable constructions. The expenses of constructing a green building is slightly more than the conventional building but the operation and upkeep expenses are less and have excellent environmental advantages. The main difficulty is to earn these benefits with reasonable cost and within the budget. According to Ministry of Environment & Forest, India, Green Building is the "practice of creating structures and using processes that are environmentally responsible and resource efficient throughout a building life-cycle from sitting to design, construction, operation, maintenance, renovation, and deconstruction"[11].

Green Building is similar to an ordinary building only with same functional usage but the differences are there in the design concepts adopted and construction techniques used to preserve the surroundings and nature. There are tangible and intangible advantages for Green New buildings. The tangible advantages are the reduction in water usage by around 30-50 % and energy savings of about 20-30 %. The intangible advantages include improved air quality, exceptional daylighting, health, comfort & well-being of the occupants, preservation of limited national resources and other safety benefits [11].

Building Information modeling (BIM) is presently one of the prominent trends in the architecture, engineering and construction sector. It is the graphical depiction of the building in the future and also incorporates the basic, physical and intrinsic aspects of a building. Currently, in India, the benefits of BIM are utilized only for the design and not carried forward to other segments like construction and facilities management. Also, those companies in India that are providing BIM services have priced it high and the clients too are not aware that actually money can be saved by using these services in a proper manner. These obstacles are making BIM to be classified as an expensive technology to adopt.

BIM can support in various sustainable design features like: building orientation, building form analysis, day lighting analysis, water usage analysis, reducing energy needs and identifying other renewable energy options, reducing material requirement by using sustainable materials and lessening the wastage and carbon footprints [1].

BIM's tool is specially made to support energy analysis application so as to find the probable gain or loss of energy for the structure, to detect and to estimate its sustainability soon at the conceptual design phase itself. So, at the very beginning of the project delivery, the owner and the project team will be able to commence on sustainability assessment. BIM is a powerful application for sustainable design considering its ability to test, analyze, and improve your design again and again. This is termed as Building Performance Analysis (BPA) [5]. There are many energy analysis tools available presently in the industry like Ecotect, IES-VE, Green Building Studio (GBS), EnergyPlus, Equest etc which can be used in combination with BIM softwares such as Revit, ArchiCAD, Bentley, Graphisoft etc.

The objective of the study is to evaluate a Green Office Building for Performance Analysis using Autodesk Revit and Autodesk Green Building Studio. Building Performance analysis carried out in this research emphasizes on the savings in cost and environmental friendly impacts as a result of choices and methods adopted to lower the energy demand and CO_2 emissions. The social impact is also necessary and essential for achieving the sustainability criteria, but however is difficult to evaluate using BIM software. The results are compared with that of a conventional building of similar design but with no 'Green' features. Also, a design alternative available for the Green building is evaluated in GBS.

2. RESEARCH METHODOLOGY

The analysis proposed in the research mainly utilizes two softwares of Autodesk: Revit Architecture and Green Building Studio (GBS). Revit helps to design, build and maintain high quality energy efficient buildings. Any

changes in the design can easily be updated in the Revit model and makes the design and documentation easier and more reliable. GBS is a flexible cloud-based service that uses DOE-2 simulation engine. It is a dynamic and accurate tool which permits architects, engineers and designers to optimize and improve the energy usage and to ensure carbon-neutrality.

The methodology followed in this study involves identifying and visiting the Green Building selected for the study. The building chosen for the research is the Administrative Building of HPCL LPG Bottling Plant, Bengaluru which received IGBC's LEED India New Construction Platinum Rating in December 2017. The main Green Building practices and materials deployed are studied and the required drawings and other information are collected.

Table I shows the main differences in the input parameters which are considered for the performance analysis of the Green Building and Conventional Building.

TABLE I: MODEL INPUT PARAMETERS FOR ANALYSIS FOR CONVENTIONAL BUILDING AND GREEN BUILDING

Sl No.	Model Input Parameter	Green Building	Conventional Building
1.	Location	Bangalore	Bangalore
2.	Weather	Warm and humid Climate Zone; ASHRAE climatic zone 1A.	Warm and Humid Climate Zone. ASHRAE climatic zone 1A.
3.	External wall Construction	250 mm thick AAC Block Masonry Work; U value = 0.16 W/m² K	230 mm thick Brick Masonry; U value = 0.81 W/m² K
4.	Roof Construction	Vegetative Roof is provided; U value = 0.37 W/m2 K	RCC Roof slab provided; No Insulation U value = 2.5 W/m2 K
5.	Glazing	Double Glazing for curtain walls, Low e; U value =2.103 ; SHGC = 0.24; VLT = 0.35 & Double glazing with reflective film for windows; U value = 5.61W/m2 K; SHGC = 0.25; VLT =0.14	Single Glazing; U value = 6.70; SHGC = 0.19; VLT = 0.08
6.	Window to Wall ratio	20%	20%
7.	Floor Slab	Uninsulated	Uninsulated
8.	HVAC systems	Variable Refrigerant Flow System	Packaged Single Zone System with DX Coils
9.	Shading Device	Horizontal Blinds on Windows	None
10.	Occupancy Sensors	Conference, Dining and private office areas	None

2.1 Creation of Energy Model

The 3D model (Fig 1) of the building is developed in Autodesk Revit Architecture by creating a new architectural template.

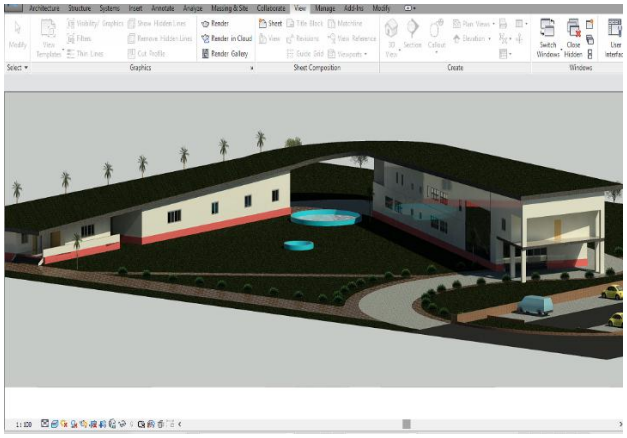


Fig 1: 3D Model of Green Building developed in Revit

After the model is created, different rooms and spaces are assigned along with the occupancy number. Then each of the space is grouped into different HVAC Zones. In the 'Heating and Cooling Load Settings', the spaces, zones and the whole building is checked for accuracy and completeness. The Energy settings are defined to create the energy model in Revit. In Revit, there are two options for generating the simulation model for Energy analysis. First one is by making use of 'Conceptual Masses', wherein the user can perform analysis at the conceptual stage of a project. And the other one is by adopting 'Building Elements'. The option 'Building elements' is selected for the analysis as the plan and other details were available.

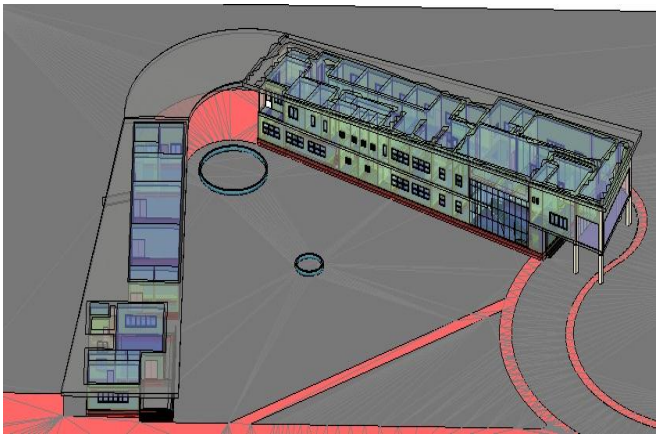


Fig 2: Energy Model created in Revit

Then this model is exported in gbXML format to Green Building Studio for further analyses like whole building analysis, carbon emission and water usage and then comparing the results of the analyses with that of a conventional building. The conventional building was assigned with parameter values as mentioned in Table I.

Fig 3: 3D Model of Conventional Building

2.2 Energy Analysis in GBS

In GBS web window, a new project is created by specifying the name, type of facility, operating schedule, location, currency, weather station and time zone. Then, the utility rates are updated as otherwise, defaults values will be considered for the evaluation.

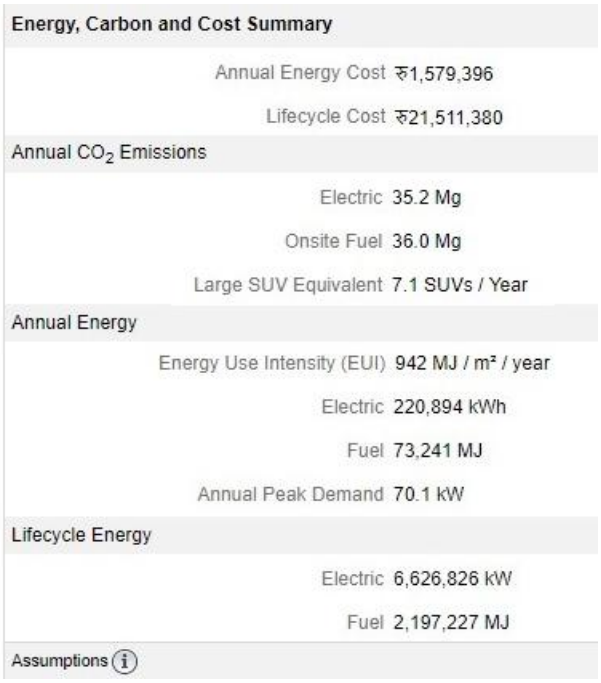
Fig 4: Utility Information added in GBS

Once the project is created, the gbXML file of the building is uploaded into it. Then it is submitted for run and the results are displayed in the GBS window. The results generated accordingly is the 'Base Run' results. In addition to this, GBS also generates 248 other 'Design Alternatives' for the model.

Energy, Carbon and Cost Summary	
Annual Energy Cost	₹1,342,910
Lifecycle Cost	₹18,290,437
Annual CO_2 Emissions	
Electric	26.8 Mg
Onsite Fuel	29.4 Mg
Large SUV Equivalent	5.6 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	674 MJ / m² / year
Electric	160,890 kWh
Fuel	63,649 MJ
Annual Peak Demand	65.3 kW
Lifecycle Energy	
Electric	4,826,700 kW
Fuel	1,909,455 MJ
Assumptions	

Fig 5(a): Energy Use Results of Green Building

The analysis primarily gives the annual energy consumption i.e. the measure of the amount of electricity and fuel the project may use during a typical one-year period and also the lifecycle energy consumption considering a lifecycle of 30 years (Fig 5(a) and 5 (b)).



Energy, Carbon and Cost Summary	
Annual Energy Cost	₹1,579,396
Lifecycle Cost	₹21,511,380
Annual CO_2 Emissions	
Electric	35.2 Mg
Onsite Fuel	36.0 Mg
Large SUV Equivalent	7.1 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	942 MJ / m² / year
Electric	220,894 kWh
Fuel	73,241 MJ
Annual Peak Demand	70.1 kW
Lifecycle Energy	
Electric	6,626,826 kW
Fuel	2,197,227 MJ
Assumptions	

Fig 5(b): Energy Use Results of Conventional Building

Fig 6 represents the annual electricity usage for different purposes like space cooling, operating fans, lights and other miscellaneous equipments etc. and the annual fuel usage for space heating, hot water etc.

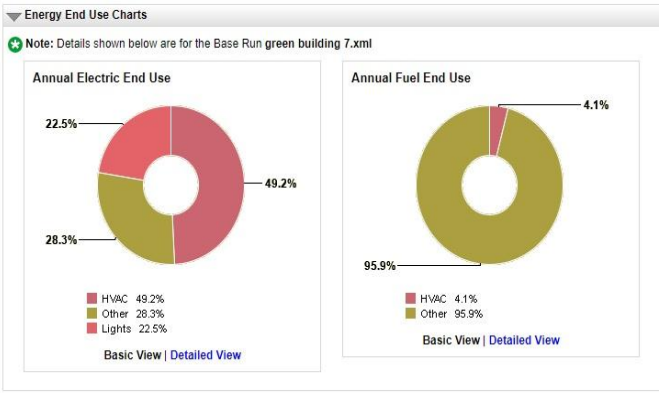


Fig 6: Energy End use charts of Green Building

Fig 7(a) shows the Base Run Carbon Neutral Potential of the Green Building which is the sum of annual CO_2 emissions of the building project from both electric and onsite fuel. Onsite Renewable Potential is a negative value because it represents the amount of carbon that can be removed from the building using renewable energy. Natural Ventilation Potential is also a negative number since it depicts the quantity of carbon that can be eliminated by using natural ventilation to cool the building than by using electricity operated cooling systems. Onsite Biofuel use denotes the amount of CO_2 that can be potentially removed by utilizing onsite biofuel in the place of natural gas, fuel etc. The net CO_2 emissions is the annual CO_2 emissions subtracted by the total carbon value that can be potentially removed.

Carbon Footprint

Base Run Carbon Neutral Potential	
Annual CO_2 Emissions	
1 Base Run	56.2
Onsite Renewable Potential	-0.6
Natural Ventilation Potential	-11.7
Onsite Biofuel Use	-36.0
Net CO_2 Emissions	7.9
Net Large SUV Equivalent: 0.8 SUVs / Year	
Assumptions	

Fig 7(a): Carbon Results of Green Building

Carbon Footprint

Base Run Carbon Neutral Potential	
Annual CO_2 Emissions	Mg
1 Base Run	71.2
Onsite Renewable Potential	-0.6
Natural Ventilation Potential	-8.7
Onsite Biofuel Use	-29.4
Net CO_2 Emissions	32.5
Net Large SUV Equivalent: 3.3 SUVs / Year	
Assumptions	

Fig 7(b): Carbon Results of Conventional Building

From Fig 7(a) and Fig 7(b), there is a significant difference in the base run CO_2 emission values of Green Building and Conventional Building.

Fig 8(a) and 8(b) shows the estimated water use for the Green Building and Conventional Building respectively based on the occupancy of the building and the building type. In general, it displays the total water requirement for the building and the landscape, indoor water requirement for the domestic use and cooling, outdoor water requirement for irrigation and other uses and the net utility-supplied water needed by the building and the landscaped area.

Net-zero measures like Rain Water Harvesting, Grey water Reclamation, Native vegetation Landscaping and Potable water sources in the site have been added in the Green Building which affects the net utility. But these net-zero measures were omitted in the analysis of Conventional Building. Also, efficient fixtures like low-flow sinks, toilets, water less urinals etc. were considered for the estimation of water in the Green Building whereas these were excluded in the Conventional Building.

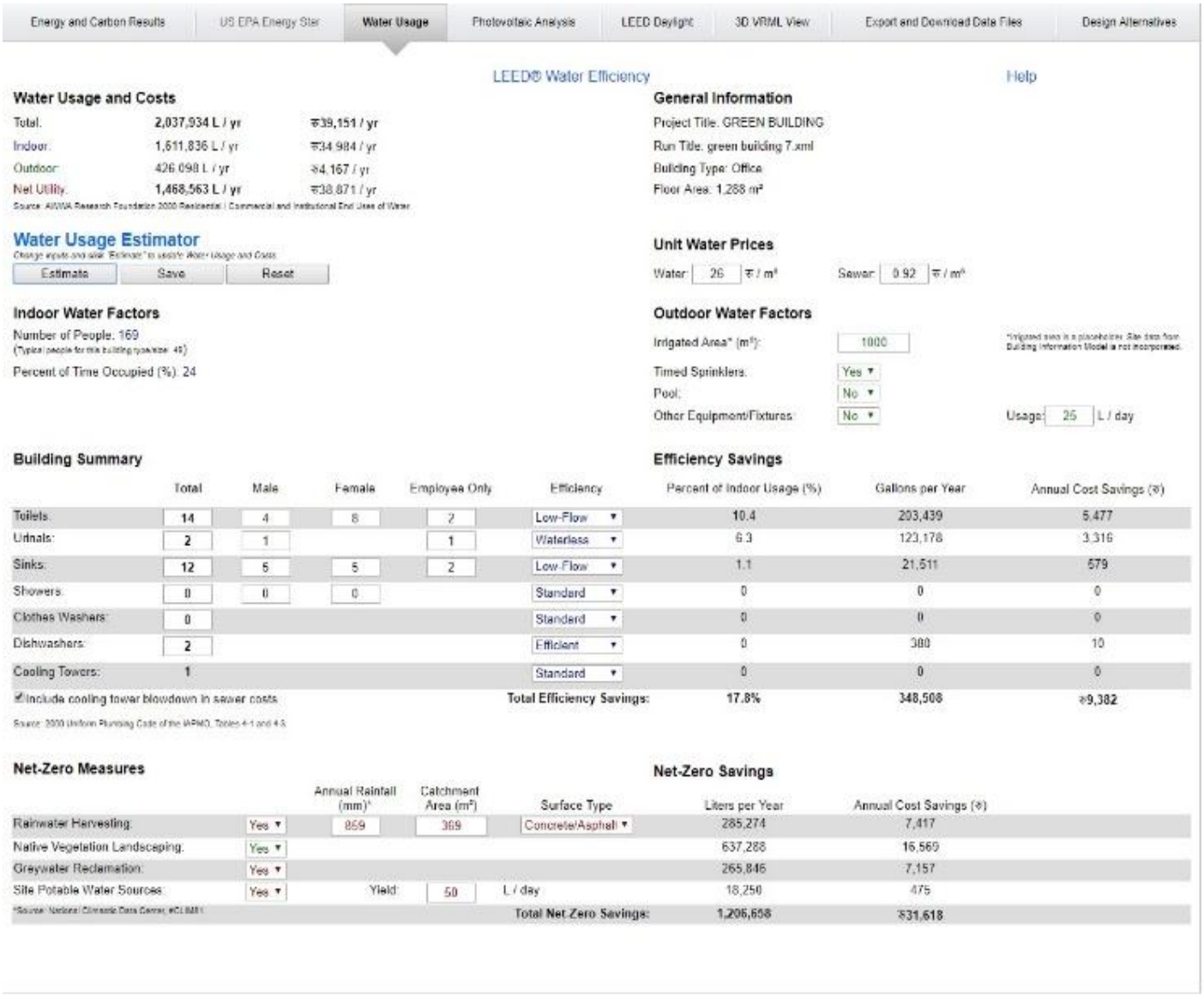


Fig 8 (a): Water Usage Estimation for the Green Building with Net- zero measures applied.

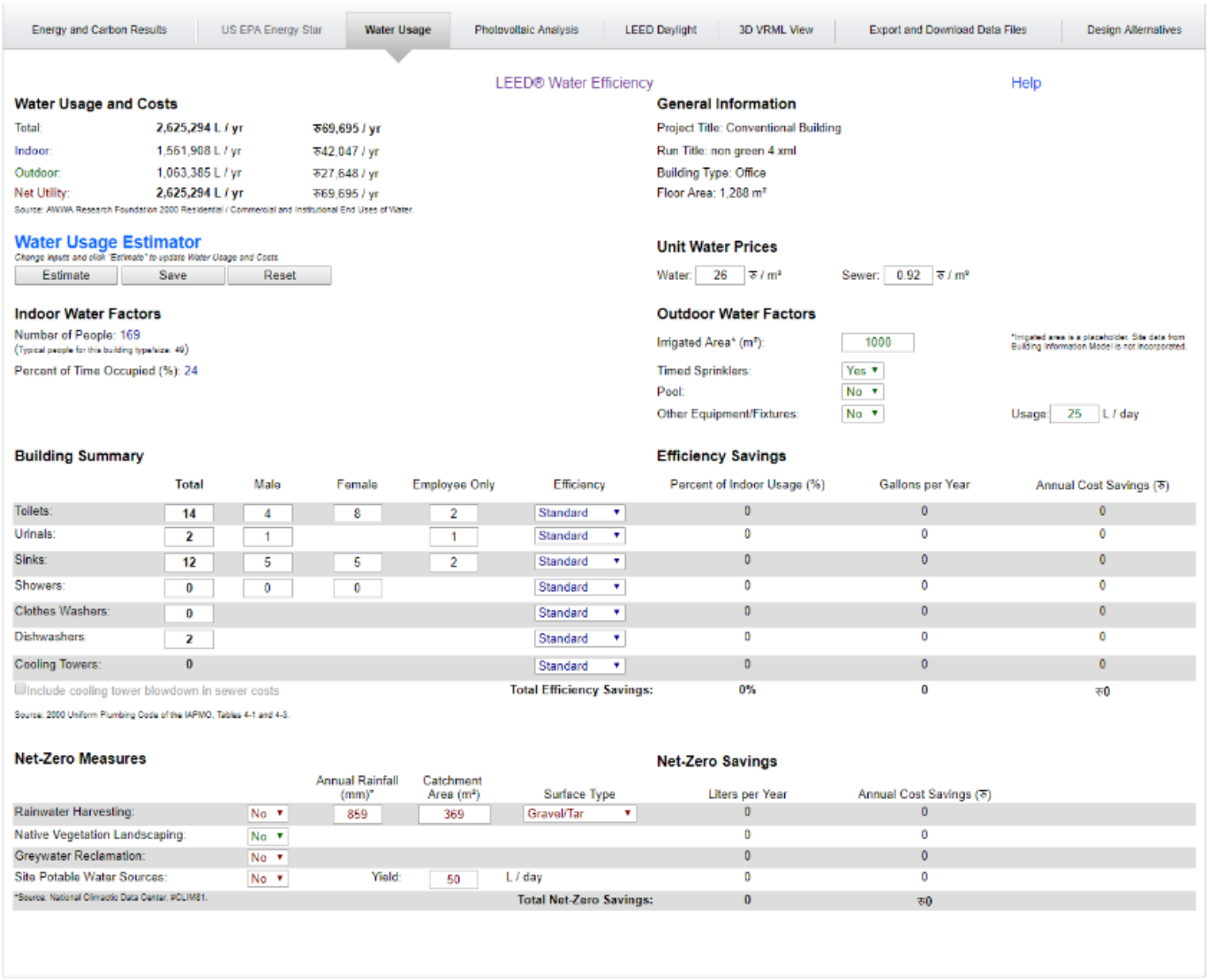


Fig 8(b): Water usage Estimation for Conventional Building with Net- zero measures excluded

2.3 Design Alternative

In GBS, there is a provision to change characteristics of walls, roofs, HVAC system, Orientation, Day lighting Efficiency etc. so that an energy efficient structure is finally achieved. In this study, the following settings were changed in the Green Building Model and their effects were studied.

- Wall Construction was changed to Insulated Concrete Form Wall.
- Window to Wall Ratio -30%
- Occupancy, Daylighting sensors and controls were added.
- Orientation- +150

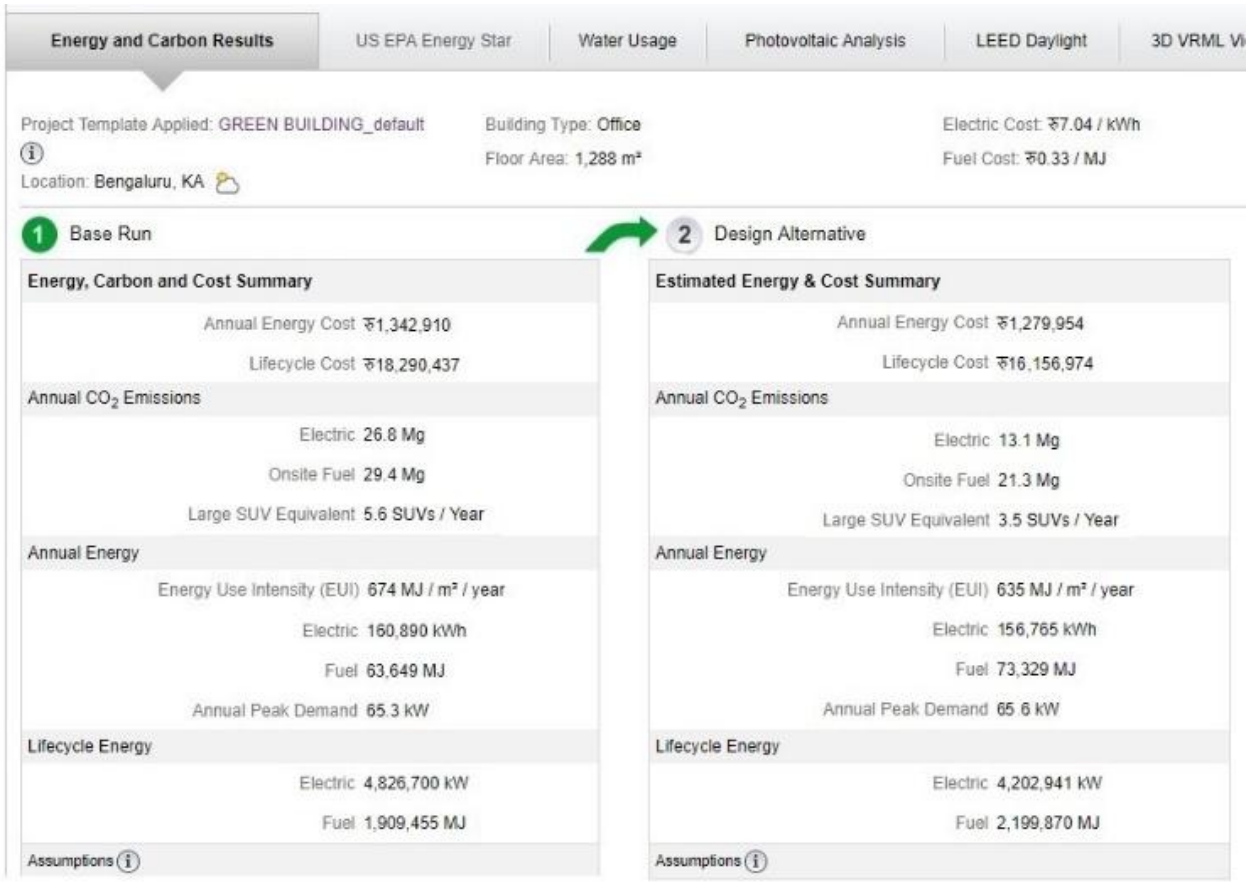


Fig 9: Base Run and Design Alternative Energy Usage Results

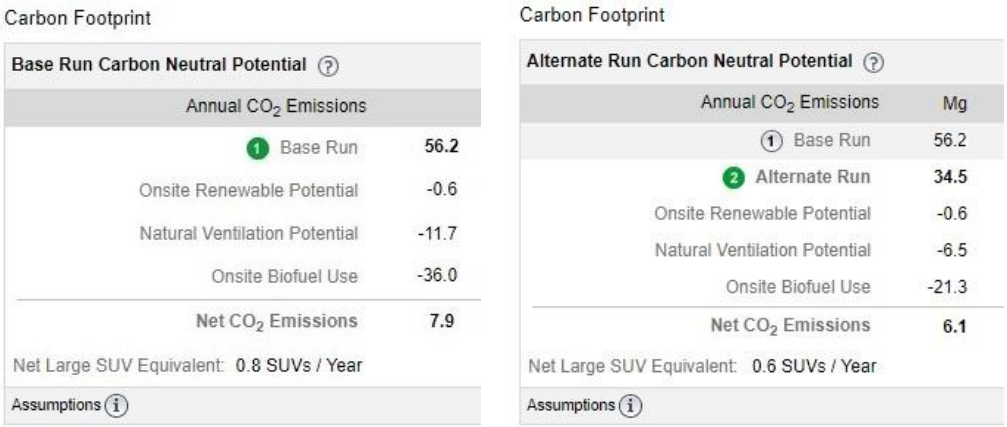


Fig 10: Base Run and Design Alternative CO2 emissions Results

From Fig 9 and Fig 10, it is evident that the variations in some parameters when applied to the Green Building have produced positive and beneficial outcomes to the surrounding environment. In this manner, more design alternatives can be explored to arrive at the finest design for a building project in terms pf sustainability.

3. RESULTS & CONCLUSIONS

Building Performance Analyses carried out for a Green Building and a conventional building of same area show that there is about 15% savings in Annual Energy Costs for the Green building compared to the conventional Building. Also, the Annual CO_2 emission has also reduced by 21% for the Green Building as against that of Conventional Building. Annual Water usage reduction for the Green Building is 22.3% which has features like rain water harvesting system, Native Vegetation landscaping, Grey water Reclamation and potable source of water at site compared to a conventional building. Annual Water costs can be reduced by 44.2% by constructing the Green building in place of the Conventional building. A Design Alternative for the Green Building was also evaluated with changes in orientation, external wall properties, window to wall ratios and with an addition of occupancy and

Daylighting sensors. The Design Alternative gave about 4.7% Energy Cost Savings and about 38.6% Reduction in CO_2 emissions compared to the Green Building. Thus, the research gave significant savings in energy costs, water usage and reduction in CO_2 release for the Green Building. Therefore, it is apparently clear from the study that constructing a Green Building is always beneficial to the nature and the environment. Also, with the help of this sustainable design application, various aspects of sustainability can be explored by the option of generating design alternatives. Various design parameters can be combined to achieve less energy consuming and less carbon emitting self-sustainable building.

4. LIMITATIONS AND FUTURE SCOPE

1. The software structure developed for analyzing sustainability requires the BIM model to be exported in various formats, such as gbXML, to an external software window. This can result in data loss and errors due to multiple data entries resulting in unreliable building performance analysis results.
2. Although the carbon emission value during the building's operational stage can be derived from the analysis, total carbon emissions throughout a building's life cycle, including the stages of building materials production and transport, construction, use, and demolition cannot be retrieved from the technology. This involves many procedures and more complexity, and will therefore demand further research.
3. The analysis generates the results of annual energy usage and the lifecycle energy usage up to 30 years. But there are other energies like embodied energy and demolition energy which are involved in other stages of a building's lifecycle such as material production and demolition respectively, which cannot be analyzed using the proposed methodology.
4. Analysis of Green Building using BIM requires high skill and the person performing the analysis should have a substantial knowledge on functional aspects of sustainability analysis.
5. Also, there are various Green factors which cannot be incorporated into the building model and therefore the analysis. For example, usage of Low emitting materials like paints, adhesives, sealants etc. with VOC values specified earlier cannot be added to the analysis. This may in actual create difference in the results.

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