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A Comprehensive Cost Benefit Analysis of Green Buildings

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Abstract—*As the Earth's population continues to escalate and the aspiring countries pursue their resource utilization indiscriminately, it is necessary to ascertain, how we, as a planet, use our scarce resources judiciously. India accounts for nearly about 5.5% of the World's energy to feed 17.74% of the Earth's population. About 33% of this energy is consumed by the building segment, thus exposing the unsustainable nature of the sector. This study presents the financial aspects of a Green Building over a Conventional Building considering New Delhi's climatology based on criteria published by Green Rating for Integrated Habitat Assessment (GRIHA). The cost calculation is estimated on a projected Green Building (10.0 m × 7.0 m) modeled in AutoCAD and evaluated on Microsoft Excel Sheet and CostMiner software. Findings show that an increase in the initial investment of about 9.702% to support green design typically makes the initial investment equivalent after a payback period of 16 years while computing it on Net Present Value with an inflation rate of 3.8% and interest rate of 10.5%.*

Keywords*: Green Building, Sustainable Development, Environment, Design Parameters, Costing and Estimation.*

1. INTRODUCTION

The recent decades have witnessed a rapid urbanization coupled with a significant increase in the building sector requirements for the city causing a boom in the economy but posing devastating repercussions for the environment. These unplanned and unsustainable construction practices have posed huge burden on material supply and is contributing up to 30% of the greenhouse gas emissions, about 70% of the waste output, nearly 65% of the electrical consumption and around 15% of the water consumption [1]. Considering the severity of the issue, it seems eminent to use an appropriate design criterion that will try to minimize such overhauling impacts on the environment. For this reason, Green Building is considered as a viable alternative option incorporating the principles of sustainable development and catering to the needs of the present times [2]. Indian Green Building Council (IGBC) defines a Green Building as a building that uses less water, optimizes energy efficiency, conserves natural resources, generates less waste and provides healthier spaces for occupants, as compared to a conventional building. IGBC also provides rating system such as Green Rating for Integrated Habitat Assessment (GRIHA) and Leadership in Energy and Environmental Designs (LEED-India) which acts as a benchmark to measure sustainable design practices and award green certification to the building. LEED – India also provides a platform to the building owners, developers, consultants, architects, project managers and facility managers with tools that they will require to design, construct and operate green buildings.

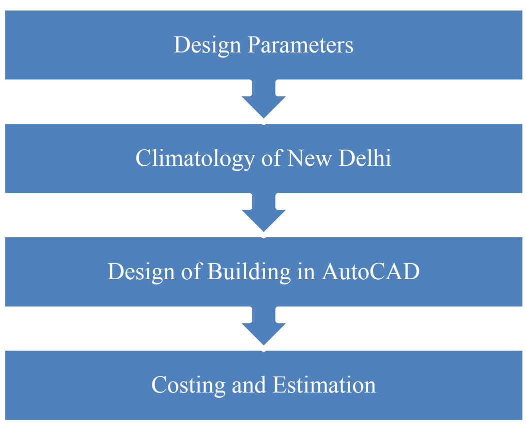
At first glance, the higher initial price and other additional resources required to build green buildings may look like a burdensome cost, but in-depth analysis reveal this insight to be just illusory. It has been observed that the additional costs are countered by the long-term savings. Like a good investment, the original costs will payback over a period of time. The aim of this paper is to propose a neutral and evidence-based analysis of the costs and benefits of this viable alternative. To determine the viability of sustainable building, a new green building has been suggested and its cost benefit analysis is performed.

2. LITERATURE REVIEW

Green building is a building whose construction and lifetime of operation reassure the healthiest possible environment. The green building tools are contrived from the locally sourced eco-friendly materials that offer a healthy environment assembled on the traditional and architectural heritage. Yet, this criterion seems to face several obstacles. Gou et al. [3] has described certain issues in this segment such as higher initial construction costs, complicated design, additional time of searching for the alternatives of the conventional building material, certification mechanism and a protracted payback period of around 20 years that impede the sector's growth. The higher initial costs and risks of green design technology may dissuade new investors from commitment to green technology [3]. Hwang and Tan [4] also indicated that the ambivalence of the actual costs and the social benefits obtained is a major barrier to the growth of green buildings.

Cost-benefit analysis is a quantitative technique which computes economic profitability and determines return on investments along with the payback period [5, 6]. The initial higher costs incurred by adopting green buildings are evaluated against the extra financial benefits arising due to the principles of green technology. A prominent model of the mentioned relationship is the impact of indoor environmental qualities (IEQ) on employee productivity [7-9]. The condition of working surroundings and comfort has a considerable sway over occupant efficiency and well-being [10]. Higher employee efficiency means higher financial gains for the organization [11]. McGraw-Hill conducted a survey concerning engineers, contractors, architects and building owner's involvement, habits and perceptions about green buildings. He observed that while switching from conventional building to green technology, average building's value increases by nearly 7.5%, operating cost decreases by around 8.5%, rents appreciates by 3%, occupancy rate rises by about 3.5% and Return on Investment improves by nearly 6.6% [12].

3. RESEARCH METHODOLOGY



3.1 Design Parameters

While computing the cost benefit analysis, the elementary design of a green building and a conventional building is assumed to be the same. However, the initial cost of green building in our design comes out to be 9.702% more than the conventional building due to the incorporation of the following Green features:

3.1.1 Site selection. The location of the building is selected in such a way that it is favored by natural geological features, receive adequate amount of solar energy and is surrounded by natural vegetation [13].

3.1.2 Orientation of the Building. The Building is aligned in such a way that it receives utmost solar light during day time and simultaneously inhibits the heat entrapping, thereby reducing the load on air conditioning systems. Keeping the geographical location of New Delhi in consideration, longer axis of the Building should be oriented along North – South direction as shown in the Figure 1.

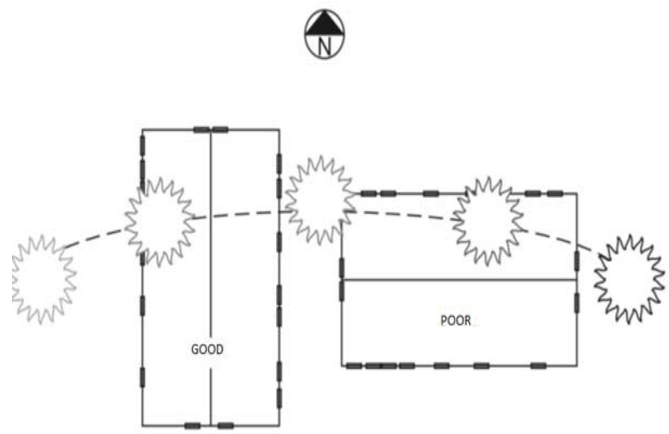


Figure 1 – Orientation of the building [14]

3.1.3 Landscape features. Natural vegetation, trees and plants on-site must not be harmed and should be promoted into the landscape, helping to prohibit the erosion of soil. Water consuming fibrous flowering plants should be planted in between them, thus maximizing the efficient use of water. Plantation of Deciduous trees should be promoted in Monsoon influenced climate as they provide adequate shade during peak summer and allows sufficient heat entrapping during winter by shedding their leaves as shown in Figure 2.

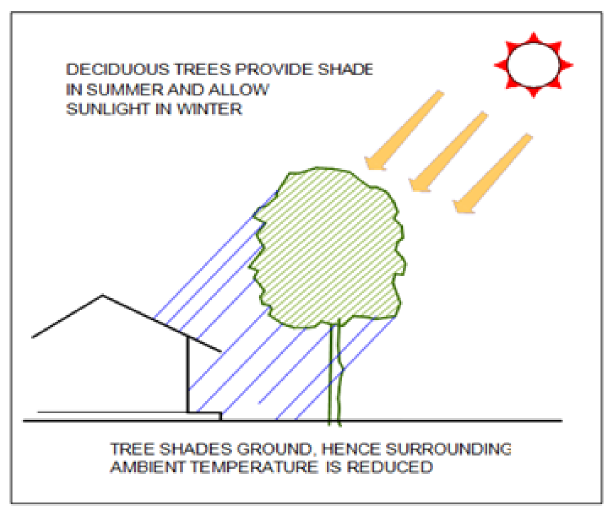


Figure 2: Landscape features [14]

3.1.4 External Insulation. Foam insulation should be sprayed on the external walls of the building which hardens and expands instantaneously, thus reducing the labor and material cost.

3.1.5 Usage of Glazed Window Glass. Glazed window glasses are provided in order to reduce thermal transmittance, increase day lighting and avoid sound proofing.

3.1.6 Rain Water Harvesting. Run-off from storm water and rain water on roof top are straight forwarded to the storage tank. A pressurized pipe under gravity is connected and water is used for irrigation [15]. Thus, principles of 3R – Reduce, Reuse and Recycle are incorporated.

3.1.7 Doors. Factory developed trusses, pre-hung and pre-fabricated doors allow for efficient use of scarce raw materials. This also decreases the quantity of debris at site, thus reducing the site pollution. Ample overhangs are also provided to protect against direct summer sun.

3.1.8 Indoor features. The building is provided with eco-friendly tiles, colored lime plaster, sand lime bricks, trombe wall, cavity wall and other such features which are termite and water resistant. Use of low Volatile Organic Compounds (VOC) material is recommended in order to reduce the emission of smog forming compounds [16]. This will also promote Indoor Environment Quality.

3.1.9 Provision of Solar Panels. Photovoltaic Solar panel is provided on the slanting roof as shown in Figure 3. Additional energy demand during non - solar period can be met with the conventional power grid. Solar Panels are helpful to reduce the electricity cost of the building by nearly 30%. On the basis of Latitude and angle of solar incidence, it is suggested that the tilt angle should be 28-30 degree in case of New Delhi and 10-12 degree in case of Chennai.

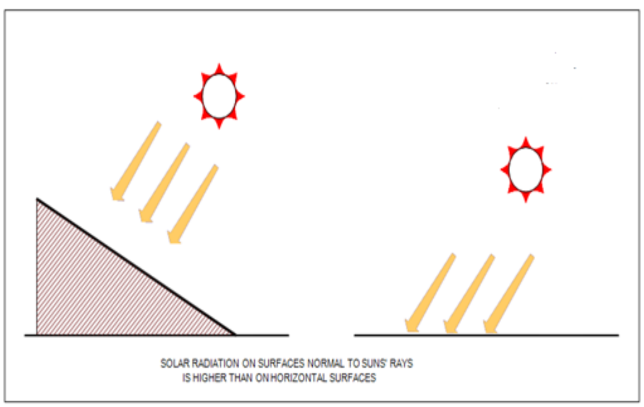


Figure 3 – Provision of Solar Panels [14]

3.1.10 Provision of electrical appliances. All electrical appliances used are energy star appliances which help in saving of electricity by nearly 30% over their conventional counterparts.

3.1.10 Provision of Sewerage treatment system. A well-organized system for segregating liquid and solid waste is used. The liquid waste is recycled after treatment and the water is used for irrigation. The solid waste is treated separately and the compost is used as manure for the local vegetation.

3.2 Climatology of New Delhi

The climatology of New Delhi has an overlapping feature of both monsoon influenced humid subtropical climate and semi-arid climate with high variation in temperatures ranging from high in summer to low in winter with major precipitation in monsoon followed by little rain in winter. The graphical representation of the monthly distribution of average temperature and precipitation for the city is shown in the Figure 4.

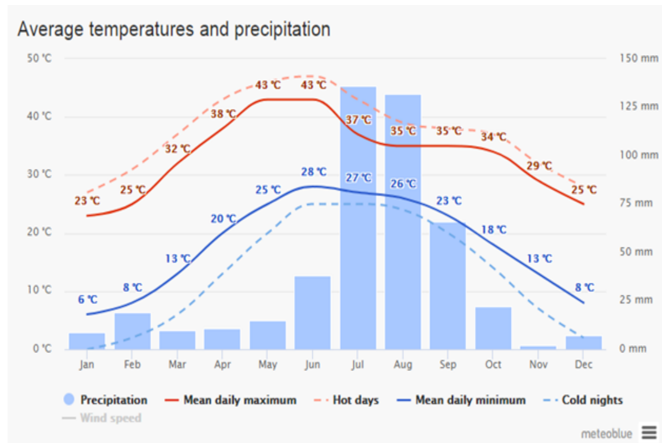


Figure 4 – Average temperature and precipitation [17]

The monthly graphical representation of the number of cloudy, sunny and precipitation days for the city is shown in the Figure 5.

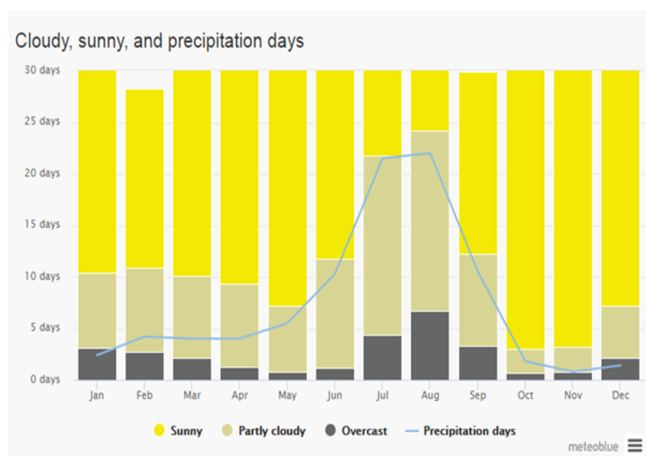


Figure 5 – Cloudy, sunny and precipitation days of New Delhi [17]

3.3 Design of Building in AutoCAD

A single storey 10.0 m × 7.0 m rectangular building plan is prepared for New Delhi. It has a single Bedroom, one Bathroom, one Kitchen and one Lobby. Its plan on AutoCAD is shown in the Figure 6.

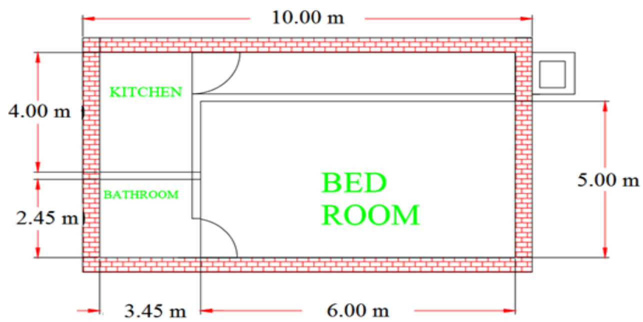


Figure 6 – Plan of the building in AutoCAD

The front elevation phasing south guides entry into the house that leads to the Hall adjoining Bedroom towards West and Kitchen towards North. The dimensional aspect of the building is shown in the Table 1.

Table 1 – Dimensions of the building

Description	Unit	Size
Number of Floor	1	10.0 m x 7.00 m
Bed Room	1	6.00 m x 5.00 m
Bath Room	1	3.45 m x 2.45 m
Kitchen	1	4.00 m x 3.45 m
Lobby	1	6.00 m x 1.45 m

The building is modeled in AutoCAD. Its 3-D view is depicted in Figure 7.

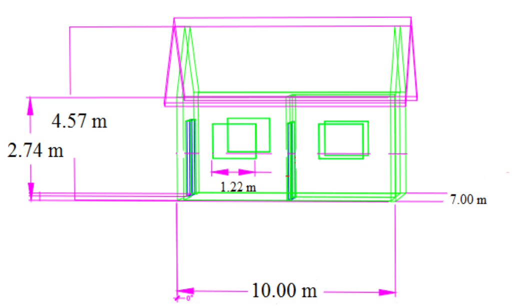


Figure 7 – 3-D view of the Building modeled in AutoCAD

3.4 Costing and Estimation

The initial cost of the Green Building has come out to be □635411. This is 9.702% more over a Conventional Building estimated at □579212. The graphical representation of the construction activities for both the building is depicted in Figure 8.

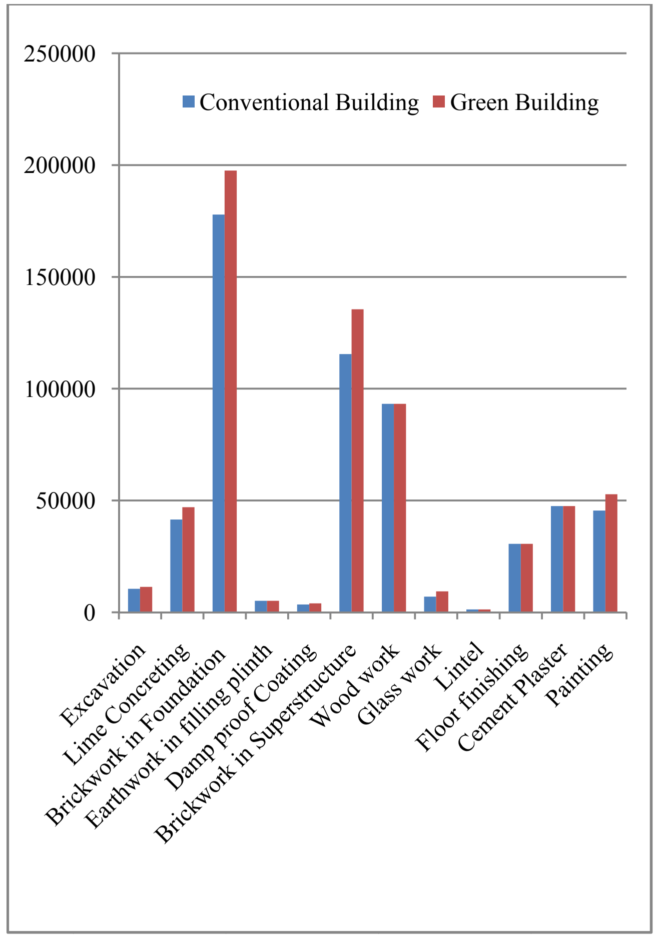


Figure 8– Graphical representation of Construction cost of Green Building and Conventional Building

The Solar Panel used can provide nearly 8 hours of electricity needs of the building during daytime. This helps in saving of nearly 38.7% of kWh units of electricity, thus bringing financial gains [18]. The graphical representation of energy utilization on monthly basis is shown in the Figure 9.

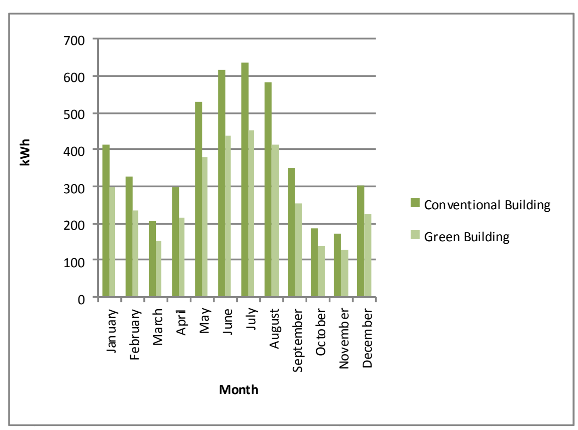


Figure 9 - Graphical representation of Monthly Comparison of Energy utilization of Conventional and Green Building

The annual electricity consumption of Green Building is 3331.118 kWh units. This is 38.7% lesser than the energy consumption of the Conventional Building. The annual statistics are shown in Table 2.

Table 2 – Annual electricity consumption of Conventional Building and Green Building

Building	kWh per year
Conventional Building	4620.4
Green building	3331.118

The payback period is estimated by computing the number of years it will take to recover the initial investment. Payback period of the Green Building incurring extra initial cost of □56200 is 16 years while computing it on Net Present Value with an inflation rate of 3.8% and interest rate of 10.5%. Figure 10 illustrates the year wise returns of the green building from the year of switching.

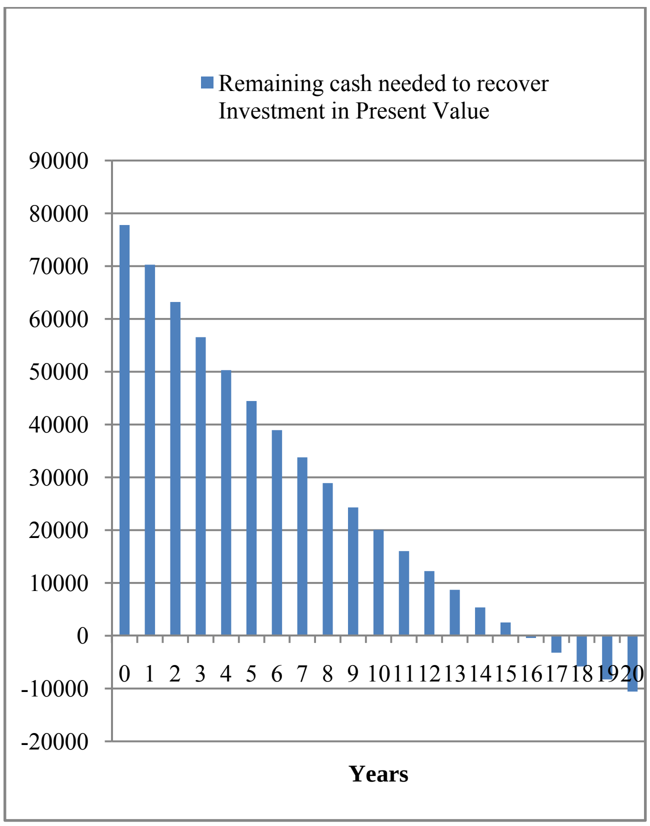


Figure 10 – Determination of Payback Period for Green Buildings

4. CONCLUSION

The potential gains of the Green Buildings can be classified into five categories namely economical savings, social and community benefits, government aspects, environmental harmony and others. Figure 11 shows the flow chart of the potential benefits.

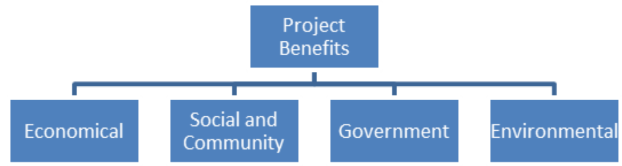


Figure 11 – Classification of potential gains of Green Building

4.1 Economic Savings

The green technology is economical as a lot of savings are accrued from the electricity and water recycling. Nearly 38.7% of electricity is generated from the solar panels and water is recycled from the rainwater harvesting mechanism. The banking system can promote the sector by investing more, thus elevating the economy.

The government should also intervene and provide subsidies in order to achieve its Nationally Determined Contribution and objectives of Paris Climate Agreement.

4.1.1. Increased Productivity. The relationship between working surroundings and employee efficiency has a direct influence on the organization's profit. The major elements of the work environment depend upon the physical layout, comfort level and environmental condition such as artificial lighting, ventilation system and natural lighting. They subsequently reduce the employee absentia and increase the employee productivity and company's profit.

4.2 Social and Community benefits

The principles of Green Building recommend the use of locally available materials. They lessen the impact on the environment by subsequently reducing the excess pollution owing due to the transportation of materials. The segment also boosts employment in the region catering from managerial rank to grass root laborers. Since the green building is a new journey, lots of new door would be open in this industry. This will also promote entrepreneurship amongst the younger generation.

4.3 Government aspect

With the boost in the job creation and entrepreneurial opportunities coupled with the increased investment from the banking sector and subsequent following by the booming economy, the government would be able to realize more tax revenues. The government should use these extra resources in Research and Development in order to access cheaper and viable technology so that India would become a global leader to promote sustainable development and fight climate change.

4.4 Environmental harmony

The Green Building is so designed in order to optimize the daylight utilization and reduce the subsequent heat gain. The provision of atrium permits passive solar shading. The water supply is recycled through rain water harvesting. Energy demand is met by Photovoltaic solar panels.

5. ACKNOWLEDGEMENT

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