PLANNING AND DESIGN OF NET-ZERO ENERGY RESIDENTIAL BUILDING (NZERB)

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ABSTRACT

The global energy scenario has undergone a drastic change in the last two decades increasing day to day, increase in consumption has led to environmental pollution resulting in global warming and ozone layer depletion. The indoor environments are becoming increasingly important for human comfort and health point of view. It is estimated that almost 50% of global energy demand is due to buildings. Therefore, it has become necessary for a change in the global scenario, environment and energy consumption which led to the approach of green building and demand for alternative renewable energy sources like solar energy, Hydel energy, Wind Energy, etc. Green building an energy optimised building which can also be called as Net-Zero Energy Building (NZEB) is one which uses less water, optimizes energy efficiency, conserves natural resource, generates less waste and provides healthier spaces for occupants as compared to a similar regular conventional building.

This paper is a study on a project that includes design of an On-Grid Solar Power System for the building under consideration. As a part of the project a (G+1) storey residential building is considered in order to compare the effective cost difference between the conventional and Net-Zero Energy Residential Building (NZERB) which is a main aspect in present scenario.

The cost comparison between the two buildings has shown an increase of in the cost of construction of Net-Zero Energy Residential Building (NZERB) compared to conventional building. This increase in constructional cost is much more less when compared to the overall maintenance of the conventional building. To summarize the initial cost of a Net-Zero Energy Residential Building (NZERB) may be high compared to the conventional building but the through-life maintenance expenditure of the conventional building compared to Net-Zero Energy Residential Building (NZERB) is very high thus, making Net-Zero Energy Residential Building (NZERB) the emerging trend.

Keywords: NZERB, Green Buildings, Solar Power System, Renewable Energies.

Introduction

1. Origin of Buildings

Building construction is an ancient human activity. It began with the purely functional need for a controlled environment to moderate the effects of climate. The hunter-gatherers of the late Stone Age, who moved about a wide area in search of food, built the earliest temporary shelters that appear in the archaeological record. Excavations at many sites in Europe dated to before 12,000 B.C show circular rings of stones that are believed to have formed part of such shelters. Constructed shelters were a means by which human beings could adapt themselves to a wide variety of climates and become a global species. Many trends mark the history of building. One is the increasing durability of the materials used. Early building materials were perishable such as leaves, branches and animal hides. Later, more durable natural materials such as clay, stone, timber and finally, synthetic materials such as brick, concrete, metals, and plastics were used.

2. Green Buildings

Green buildings are built from green, rapidly renewable, non-toxic, reusable, and recyclable materials such as lumber, bamboo, straw, recycled metal/stone, sheep wool, compressed earth block, concrete, cork etc. In general, the green buildings comprise of the following advantages over normal buildings

2.1 Need for Green Buildings:

Factors affecting for the Need the for Green Buildings are as follows:

a. **Temperature Regulation**
b. **Indoor Air Quality**
c. **Indoor Environment Quality**
d. **Indoor Environment Quality**
e. **Maintenance**
f. **Improved Productivity**

These factors play a predominant role in the reason why the global scenarios are tending towards the concepts of Green Buildings, Renewable Energy Systems and as a whole NZERBs.

3. NET ZERO ENERGY BUILDING (NZEB)

A zero-energy building, also known as a zero-net energy (ZNE) building, net-zero energy building (NZEB), or net zero building, is a building with zero net energy consumption, meaning the total amount of energy used by the building on an annual basis is roughly equal to the amount of renewable energy created on the site, or in other definitions by renewable energy sources elsewhere. These buildings consequently contribute less overall greenhouse gas to the atmosphere than similar non-ZNE buildings. They do at times consume non-renewable energy and produce greenhouse gases, but at other times reduce energy consumption and greenhouse gas production elsewhere by the same amount. Traditional buildings consume 40% of the total fossil fuel energy in the US and European Union and are significant contributors of greenhouse gases. The zero-net energy consumption principle is viewed as a means to reduce carbon emissions and reduce dependence on fossil fuels and although zero-energy buildings remain uncommon even in developed countries, they are gaining importance and popularity.

Most zero-energy buildings use the electrical grid for energy storage but some are independent of the grid. Energy is usually harvested on-site through energy producing technologies like solar and wind, while reducing the overall use of energy with highly efficient HVAC and lighting technologies. The development of modern zero-energy buildings became possible not only through the progress made in new energy and construction technologies and techniques, but it has also been significantly improved by academic research, which collects precise energy performance data on traditional and experimental buildings and provides performance parameters for advanced computer models to predict the efficacy of engineering designs.

The net zero concept is applicable to a wide range of resources due to the many options for producing and conserving resources in buildings (e.g. energy, water, waste). Energy is the first resource to be targeted because it is highly managed, expected to continually become more efficient, and the ability to distribute and allocate it will improve disaster resiliency.

4. Green building versus Net-zero energy building

The goal of green building and sustainable architecture is to use resources more efficiently and reduce a building's negative impact on the environment. Zero energy buildings achieve one key green-building goal of completely or rather very significantly reducing energy use and greenhouse gas emissions for the life of the building. Zero energy buildings may or may not be considered "green" in all areas, such as reducing waste, using recycled building materials, etc. However, zero energy, or net-zero buildings do tend to have a much lower ecological impact over the life of the building compared with other "green" buildings that require imported energy and/or fossil fuel to be habitable and meet the needs of occupants.

Because of the design challenges and sensitivity to a site that are required to efficiently meet the energy needs of a building and occupants with renewable energy (solar, wind, geothermal, etc.), designers must apply holistic design principles, and take advantage of the free naturally occurring assets available, such as passive solar orientation, natural ventilation, day lighting, thermal mass, and night time cooling.

5. Objective of Green Buildings

- To develop buildings which use the natural resources to the minimal at the time of construction as well as operation.
- Maximizes the use of efficient construction materials and practices.

- To ensure minimum negative impact on the environment by the construction and operation of a building.
- To preserve the external environment to the building location; to improve the internal area for the residents of the building; and also preserve the areas which are not close to the building.
- Reduction in the amount of energy that is consumed in lighting, air conditioning and other building operations.
- Green Buildings emphasize more on natural lighting and concepts of temperature control and efficient design to further reduce the carbon footprint as well as reduce cost of operation.
- The target is to be able to achieve zero water table negative impact from the green building.
- Hygiene and proper conditions inside the building also help in boosting human productivity.

6. Green Building Materials

Green building materials can be defined as materials with overall superior performance in terms of specified criteria. The following criteria are commonly used:

- Locally produced and sourced materials
- Transport costs and environmental impact
- Occupant needs and health considerations
- Financial viability
- Recyclability of building materials and the demolished building
- Waste and pollution generated in the manufacturing process
- Energy required in the manufacturing process
- Use of renewable resources
- Toxic emissions generated by the product
- Maintenance costs

7. Green rating systems

The green building movement has led to the emergence of various green rating systems. The predominant ones are:

- BREEAM – UK
- LEED – USA
- Green Star – Australia
- CASBEE – Japan
- Green Mark – Singapore
- NABERS – New South Wales
- LEED – India
  Administered by the Indian Green Building Council (IGBC);
- GRIHA - India

Green Rating for Integrated Habitat Assessment developed by TERI (The Energy and Research Institute).

8. What is known about achieving "zero energy" in buildings?

In the literature dedicated to Zero Energy Building the authors frequently emphasize the lack of common understanding of what should be equal to 'zero'. This issue has been widely discussed in numerous publications however, the question: should "zero" refer to the energy, or the CO2 emissions or maybe energy costs, still has not been unambiguously answered.

The definition of Zero Energy Building can be constructed in several ways, depending on the project goals, intentions of the investor, concern about the climate changes and greenhouse gas emissions or finally the energy costs. Taking into consideration all the above-mentioned scenarios *Torcellini, et al.* (2006) distinguish and point out advantages and disadvantages of four most commonly used definitions:

•**Net Zero Site Energy**: A site ZEB produces at least as much energy as it uses in a year, when accounted for at the site.

•**Net Zero Source Energy:** A source ZEB produces at least as much energy as it uses in year, when accounted for at the source. Source energy refers to the primary energy used to generate and deliver the energy to the site. To calculate a building's total source energy, imported and exported energy is multiplied by the appropriate Site-to-Source conversion multipliers.

•**Net Zero Energy Costs:** In a cost ZEB, the amount of money the utility pays the building owner for the energy the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year.

•**Net Zero Energy Emissions:** A net-zero emissions building produces at least as much emissions-free renewable energy as it uses from emissions-producing energy sources.

9. Achieving Net-zero energy using SOLAR POWER

To help evaluate whether a home solar electric system will work for anyone, one should consider the following:

- Your available solar resource -- do you have clear and unobstructed access to sunlight for most or all of the day, throughout the year?
- The system size -- do you have a roof or area large enough to accommodate it?
- The economics -- is it worth the investment?
- Local permits and covenants -- are there any issues with installing a system?

10. Evaluating site solar resource

The solar resource is ample for solar electric systems -- also known as photovoltaic (PV) systems -- because they can use both direct and scattered sunlight. However, the amount of electricity generated at a site depends on how much of the sun's energy reaches it. Thus, PV systems function most efficiently in the places, where it receives the greatest amount of solar energy.

Before you buy a PV system, you will want to be sure your site has enough solar energy to meet your electricity needs efficiently and economically. Your local system supplier can perform a solar site analysis for you or show you how to do so on your own. When evaluating your site, you'll also need to consider both the geographic orientation and the tilt of your solar panels -- PV modules -- as both can affect your system's performance.

11. Planning and Design of Residential Building

A structure commonly used in a building is a framed structure. Framed structure consists series of columns which are connected by means of beams at floor and road levels. Frames are characterized by resisting of members at all joints. Here, the assumed structure for analysis and design is a (G+1) Duplex Residential Building.

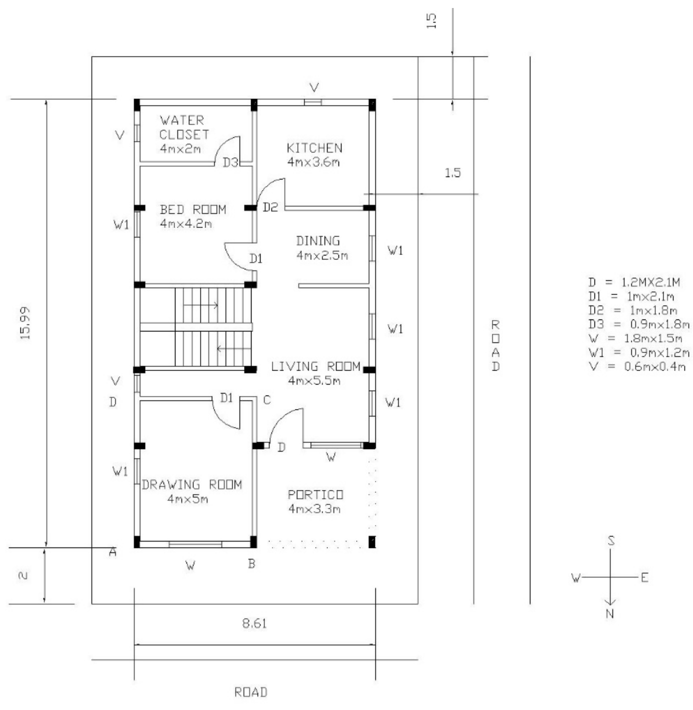

Figure 1 Ground Floor Plan

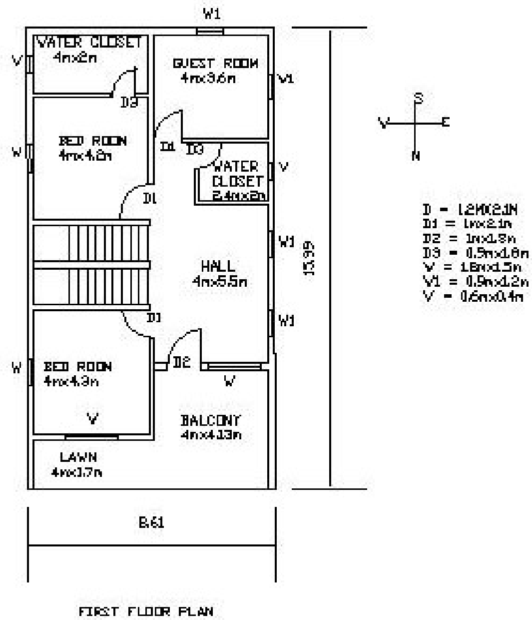

Figure 2 First Floor Plan

Analysis and design: In this project, beams and columns are designed using the software called STAAD Pro V8i and other necessary structural components are designed manually.

Specifications:

Column size: 230 mm x 425 mm
Beam size: 230 mm x 300 mm
Slab thickness: 175 mm
External Wall thickness: 230 mm
Internal Wall thickness: 150 mm
Floor height: 3.0 m

12. WORKING OF SOLAR POWER SYSTEM

Solar Power System includes different components and works in the following manner,

1. The ***solar panel*** converts sunlight into DC power or electricity to charge the battery.
2. This DC electricity (charge) is controlled via a ***solar regulator*** which ensures the ***battery*** is charged properly and not damaged and that power is not lost (discharged).
3. DC appliances can then be powered directly from the battery.
4. AC appliances need a ***power inverter*** to convert the DC electricity into 220 Volt AC power.

13. COMPONENTS OF SOLAR POWER SYSTEM

Solar Plant consists of the following components which works together to generate electricity at any place. They are:

1. Solar Panels

2. Solar Regulator
3. Solar Batteries
4. Power Inverter

Figure 3 Components of Solar Power System

14. Designing of solar power system

The Solar Power System is designed considering several factors like amount of wattage generated in a building, cost of components, life span of components and their efficiency.

It includes further steps. They are:

Step 1: Estimation of wattage power
Step 2: Size of Solar Inverter
Step 3: Size of Solar Panels
Step 4: Number of Batteries
Step 5: Size of Regulators

Step 1: Wattage Estimation
The Wattage Estimation for the Building under consideration is estimated to be **9815W** with an **2920W** Invertor per hour.

Step 2: Size of Solar Inverter
Appliance total power draw = 2920 W
To provide a small buffer or margin your minimum size inverter choice should be around 3500W.
A modified sine wave inverter with a 3500W continuous power rating will therefore be your obvious choice in this specific solar system design.

Step 3: Size of Solar Panels

Sharp company is producing 37.9% efficient solar cells; let us consider it converts 35% of their available energy into electric power. This may not sound very good, but it is much better than other solar panels where less than 14% of the energy that reaches them will be converted to electricity.
Let us consider 300W solar panels of size 2m length and 1m width.
Considering 35% efficiency of panels the power generated by a 300W solar panel = (35 x 300)/100 = 105W
The power we require for the building is 9815W. Therefore, power required by the number of charge hours for that geographic region = (9815 x 1.2)/6 = 1963W
Number of panels = 1963/105 = 18.69 say 20 panels.
Area required to place these panels = 20 x 2 = 40 m^2.

Step 4: Number of Batteries
Typical deep-cycle, lead-acid batteries cost about half as much as lithium-ion.
300W panels produce 12.5Amps, thus 20 x 12.5 A = 250 x 6 hours = 1500Ah
105Ah batteries, should be discharged to no more than 50%, thus we divide total amps by 105Ah x 50% = 50A.h = 30 number of 105Ah batteries.
For ease of possible 24V configuration, this would mean 3 in series of 10 batteries.

Step 5: Size of Regulators
Let's say we had 40A regulators.
One 300w panel produces around 12.5Amps.
The regulators are put in series
20 x 12.5 A= 250 A
So, 20 solar panels need 7 x 40 A solar regulators.

15. Comparison of costs for Conventional and NZERB

Type of Cost	Conventional Building (Rs.)	NZERB (Green Building) (Rs.)
Cost for construction	27,00,000/-	32,00,000/-
Cost for Electricity for 50 years of life span	12,50,000/-	11,25,000/-
Total Cost	**Rs. 39,50,000/-**	**Rs. 43,25,000/-**

The Estimation is carried cosindering the local rates and rounded off to the nearest round values.
By comparing, we can observe that there is an increase of 9.5% (approx.) in the cost of NZERB compared to conventional building.

Conclusions

"A Green building should create delight when entered, serenity and health when occupied and regret when departed'- perhaps this is one of the most inspiring definitions of a green building, articulated in the book 'National Capitalism'. In spite of access to a large information based on various features and techniques, and despite pioneering work in this field by architects the world over and in India, the energy institutes have not percolated to architects at large, especially in a form that can directly be implemented in their designs.

The following conclusions can be drawn through the present project work:

- Cement can be replaced by fly ash up to 20% without affecting the strength.
- Sand can be replaced by quarry dust up to 20% so that excavation of sand from river beds can be minimized.
- Regular country bricks are replaced by a cellular lightweight concrete brick (CLC bricks) which helps in effective reduction of environment exploitation and act as good insulators.
- There is an increase of 18.5% in cost of construction for Green buildings compared to that of a conventional building.
- There is a decrease of 10% in total cost for energy consumption of NZERB compared to that of a conventional building.
- There is an increase of 9.5% in total cost of operation and maintenance for NZERB compared to that of a conventional building.
- Increased cost of construction would result in significant decrease in the post constructional expenditure.
- Effective utilization of renewable energy resources like solar energy, considered under the present study which can replace the use of non-renewable energy source to a major extent.

Green building technology and Concepts of NZERB are such where in aesthetical and environmental aspects of building construction can be equally balanced creating the dream building.

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