Comprehensive Study of Zero Energy Buildings or Carbon Neutral Buildings (CEB) by using Life Cycle Assessment Tool

Ar. Disha Ashok Kumar Barik

M-Arch 3rd Semester, Environmental Architecture, Institute of Design Education and Architectural Studies, Nagpur, India

Abstract: ***'Zero Energy Buildings' or 'Carbon Neutral Buildings' (CEB) does this concept really exists? In recent times, Zero-Energy Building concept has become a popular catchphrase to describe the synergy between energy-efficient building and renewable energy utilisation to achieve a balanced energy. There are various definitions of 'zero energy' buildings. In most cases, the definition refers only to the energy that is used in the operation of the building, ignoring the wider perspective of energy use related to pre-construction and post-construction of the building which includes issues such as extraction, manufacturing, processing and transportation of materials which also requires some amount of energy. This sum amount of energy which exists in materials from its initial raw stage till its final finished product which is been used at site possess energy which is termed as "Embodied Energy". This research paper mainly focuses on the Hypothetical concept of "Zero Energy" Buildings with its qualitative assessment through life cycle assessment tool.***

Keywords: Zero Energy, Embodied Energy, Qualitative assessment, Life Cycle Assessment, Constructional phases (pre and post)

1. Introduction

Energy is one of the most important factors in economic growth and social development in all countries. A building consumes energy at different levels in every stage of the life-cycle, whereas building materials occupy a great share of this consumption. The choice of building materials can have multiple effects on a building's energy consumption over the different phases of its life cycle. Therefore, the amount of energy consumed by materials used in buildings during their life cycle is an important parameter in determining the energy efficiency of the zero energy building. As the number of these buildings increases, the need to consider embodied energy from building materials also increases, especially if an overall goal is to reduce the building's life cycle energy use. The life cycle assessment of advanced building materials and systems is paramount to significantly improving overall environmental building performance. This paper focuses on qualitative study of a zero energy building, which aims to achieve significant benchmarks not only due to current construction and operation phases but also because the materials which possess some amount of energy in the form of embodied energy used to construct these zero energy buildings have higher environmental impacts than those of traditional buildings.

2. Energy Consumption in a Building

In this era of climate change and environmental degradation, a large variety of mitigation measures such as, initiatives targeting sustainable building are urgently required. These include the construction of green buildings, utilization of building, rating systems, energy codes, and many other prescriptions. Net Zero Building projects (NZEBs) are targeting to push the envelope further, by being self-sufficient, not just in terms of their electricity consumption but with an overall minimal dependence on other natural resources. Energy consumption is rapidly increasing due to the increase in population and urbanization. In zero energy building design, the use of energy efficient building material plays an important role since the construction materials can positively support the construction in which they are used by reflecting their environmental features with their all other features into the construction. For this reason, energy saving, it is important to select energy efficient building material in the beginning of design. Energy requirements vary from region to region, depending on climate, dwelling type and level of developments, buildings consume energy at different phases and for different purposes.

1) In the manufacturing phase of construction-energy is consumed for having raw material of construction and manufacturing materials its transportation and building of the construction.
2) In the phase of using-energy is consumed for providing proper inner air quality in accordance with indoor visual, thermal, acoustic comfort conditions, and for maintenance, restoration, and renewal of the construction
3) In the phase of destruction of the construction-energy is consumed for destroying building and debris removal, obliteration of the construction waste, recovery of some construction materials/components in the recycling process.

3. Aim

The focus of the study is to understand the concept of a living zero energy building and to quantify the embodied energy within it.

3.1 Objective

a) To select an example of a zero energy building.
b) To identify and understand different parameters based on the living example selected.
c) To analyse and focus on some amount of energy that is been used in the operation of the building.

d) To identify the factors based on loss of energy during the operation of the building.

3.2 Definitions

a) Zero energy: A zero-energy building, also known as a zero net energy (ZNE) building, net-zero energy building (NZEB), net zero building or zero-carbon 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.
b) Embodied energy: This sum amount of energy which exists in materials/buildings from its initial raw stage till its final finished product which is been used at site possess energy which is termed as "Embodied Energy". It includes processes such as extraction, manufacturing, processing and transportation of materials which also requires some amount of energy.
c) Qualitative assessment: Qualitative assessment refers an inquiry- process of understanding social or human problem, based on building a complex, holistic picture, formed in words, reporting and detailed views of informants. Also explores and tries to understand beliefs, experiences, attitudes, behaviours and interactions. The end result is mostly non numerical data.
d) Life cycle assessment: It is a technique to assess environmental impacts associated with all the stages of a product's life from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling.

3.3 Living example of Zero Energy

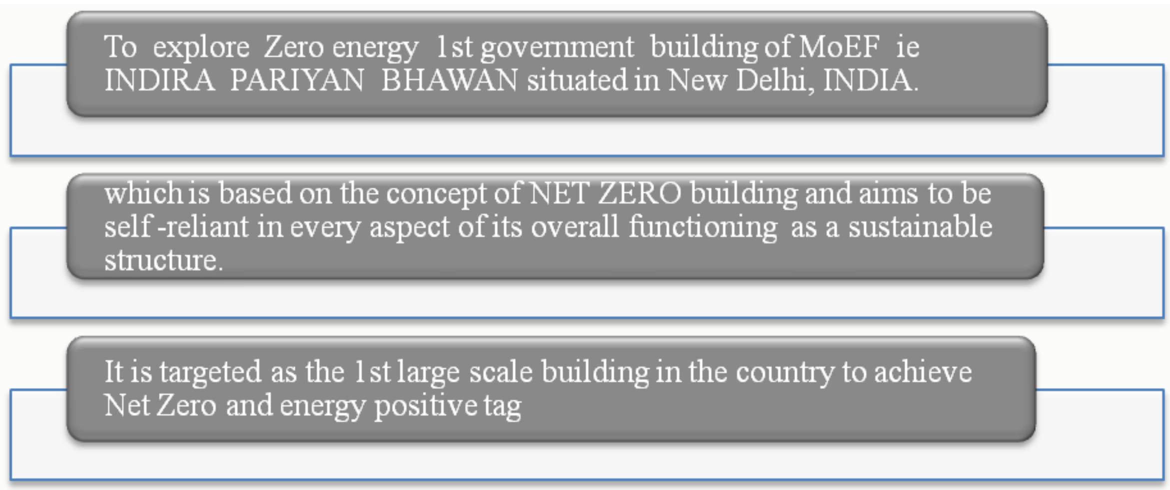

Figure 1: Represents building features
Source: Author

3.4 Background

<u>**Integrated Design Team**</u>
Client: Ministry of Environment and Forest (MoEF)
Project Coordinator: CPWD
Principal Architect: PWD
Landscape Architect: CPWD
Project Management: CPWD
Structural Design: Central Design Organisition, CPWD
MEP consultant: Spectral Services Consultants.
Green building design and certification Consultant: Deependra Prashad Architects and Planners

The land, on which the building is constructed, was originally a single storey decrepit government housing which under a change of land use was reassigned for the government office function. Despite the change in land use, the mandate of the Ministry's building remained as providing minimum change and disturbance to the surrounding ecosystem, including the predominantly green character of the surroundings, while still optimally utilizing the tight urban site of almost a hectare.

Figure 2: Represents Site plan
Source: Indira Paryavaran Kendra.pdf

This building reflects the growing role of the ministry in regulating and channelizing India's development into a sustainable paradigm. This mandate was carried forward by the Central Public Works Department at every level to design a building which is not just energy efficient but is also able to create more energy onsite than it consumes over a functional year. Apart from aiming to be a Net Zero Building, the project has also achieved the 5-star GRIHA Green Rating and is targeting the LEED India NC Platinum rating system through a slew of measures both in the passive and the active design of building envelope, the usage of materials, service provision, and also by following a range of environment-friendly processes within the construction programme.

Figure 3: represents Front Elevation of Kendra
Source: Indira Paryavaran Kendra.pdf

3.5 Descriptive Approach

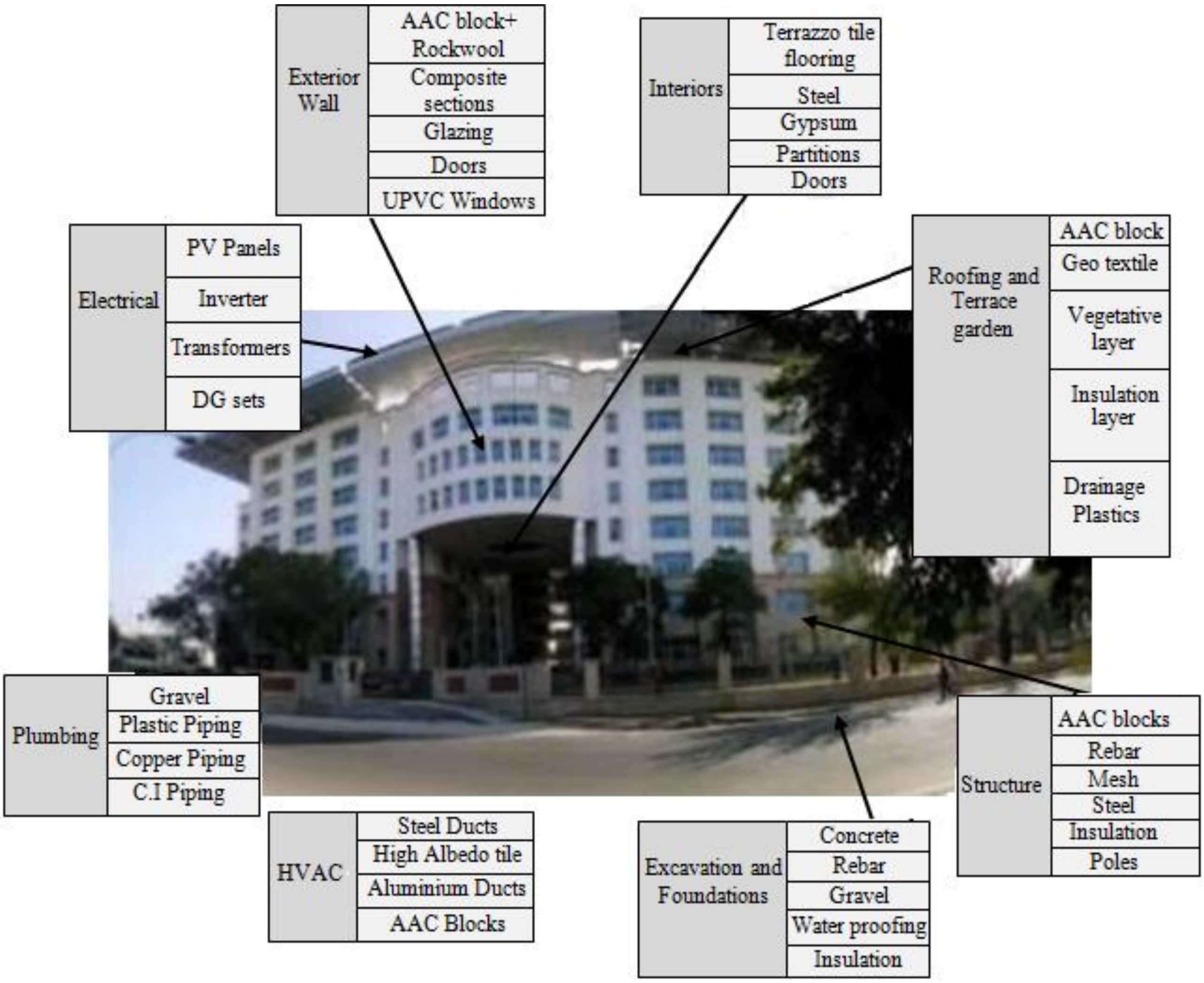

Figure 4: Illustrative material phase case-study
Source: Author

3.6 Qualitative Analysis

In this paper the definition of zero energy building is extended to include the embodied energy of the building and its components together with the annual energy use, which will serve to introduce a life cycle perspective and therefore brings the concept of 'net energy', as used into the built environment within a consistent methodology. Energy used in the building in operation plus the energy embodied within its constituent materials and systems, including energy generating ones, over the life of the building is equal to or less than the energy produced by its renewable energy systems within the building over their lifetime.

Building components such as envelope finishes, and services, which may not hold higher embodied energy initially, require a significant recurring energy. (It is the energy consumed in the maintenance, replacement and retrofit processes post construction). At the end of its service life, a building is demolished and its constituent materials are sorted, treated, and transported for reuse, recycling, or disposal to landfills or incinerators. Both the electricity and fuel are consumed directly and indirectly in the demolition and disposal processes is never taken into account.

International Journal of Science and Research (IJSR)
ISSN: 2319-7064
ResearchGate Impact Factor (2018): 0.28 | SJIF (2018): 7.426

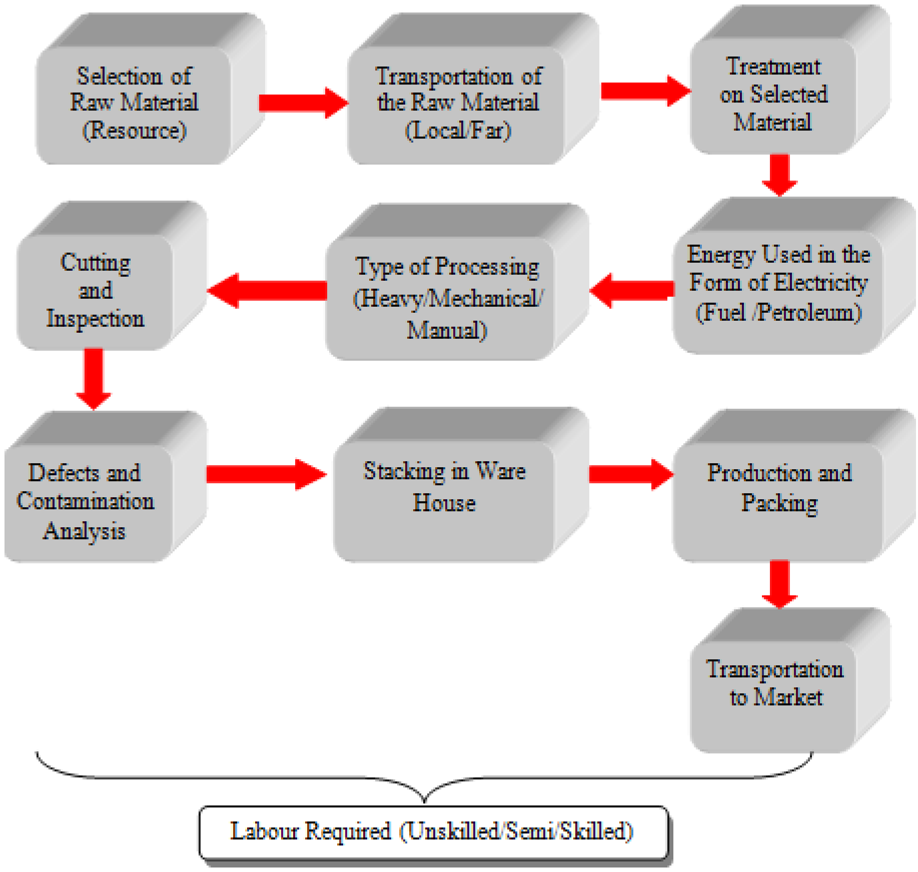

Figure 5: Stage wise material phases
Source: Author

4. Life Cycle Assessment

One method to assess the overall environmental impacts is with Life Cycle Assessment.LCA is a tool used to quantify the environmental inputs and outputs from the raw materials extraction and manufacturing of the product through the product's use phase and ultimately disposal. In a whole-building LCA, environmental impacts can be calculated at all phases-raw materials extraction and processing, product shipment to site, construction, use/maintenance, and demolition/disposal.LCA provides a standardized method for comparing the relative sustainability of all products or processes used during Pre and Post Constructional phases of the building.LCA can also identify points in a product or process cycle where environmental impacts are relatively high and changes could be made to improve the sustainability of the overall system. Thus it focuses on the environmental impacts of IPK building materials. For eg:- where the major components of the analysis, ranging from structural elements to interior flooring as well as ductwork for the Heating, Ventilation and Air Conditioning (HVAC) system and piping for plumbing. It is important to note that the PV panels do not include the cost, labour and maintenance of mounting system or the monitoring system and the associated materials with those PV system parts. Also landscaping elements which require recurrent energy, interior finishes such as carpet tiling and paints do not calculate the embodied energy required during its implementation phase. Represent a small quantity of the building's total mass. The boundaries for this study include material extraction and product processing and manufacturing defined herein as "materials phase" of the Kendra. Transportation of the building materials to the construction site, construction waste, and materials used for construction itself (eg: temporary materials) are not included. **The building material phase is becoming increasingly important as the impacts associated with the use phase of low-energy buildings decreases.** A net -zero building construction and its role in reducing operational energy led to the development of high-performance buildings, which support environmentally responsible and resource-efficient building design that aims to reduce greenhouse gas emissions and other negative environmental impacts which leads energy loss in nature. This energy loss in nature during the operational phases of construction ie during pre-construction or post-construction is never taken into account.

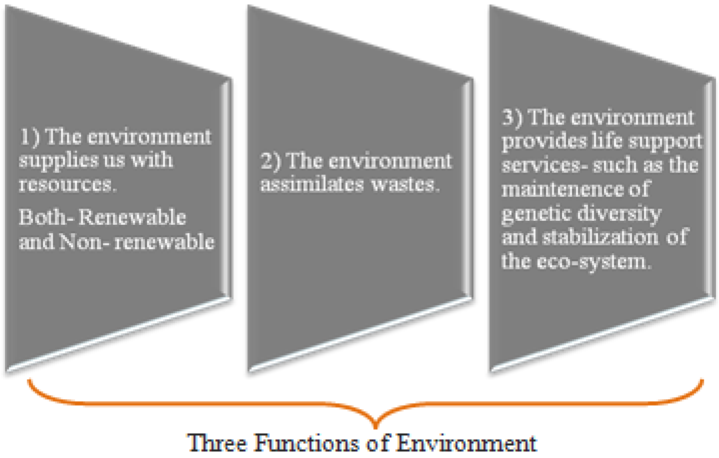

Figure 6: Interlinked Functions of Environment
Source: Author

5. Environmental Inter-linkages

The three functions of the environment are clearly linked. The transformation of resources to wastes (low entropy to high entropy) are caused by the activities of production and consumption. Absence of 2nd function, namely failure to assimilate wastes, will affect the 3rd function of the environment. Also, in a **Spaceman economy**, the earth is viewed as a single spaceship, without unlimited reserves for any resources and without unlimited capacity to assimilate wastes. Within this spaceship, if civilizations should survive, every effort has to be made to recycle wastes, reduce wastes, and conserve exhaustible energy and resource sources. Boulding's Spaceship Earth analysis was formalised in the material balance models of Ayers (1960).This balance models are based on 1st and 2nd laws of Thermodynamics. The material balance approaches are a process as a physically balance approaches between inputs and outputs.

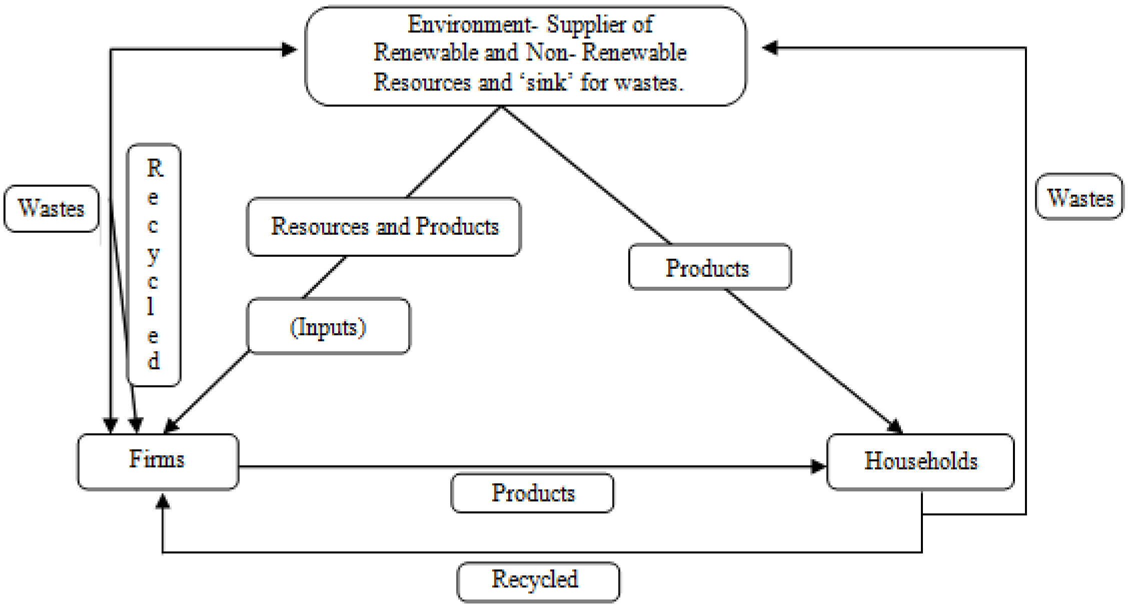

Figure 7: A Material Balance Model
Source: Environmental Economics

The material balance approach depicted in figure (Fig-7) depicts production of output from organic and inorganic inputs through various energy conservation and production process resulting into the discharge of solids, liquids and gaseous wastes. Similar wastes results from consumption activities too. Thus material and energy are drawn from the environment, used for production and consumption activities and returned back to the **environment as sink for wastes**. Matter and energy used in production and consumption activities by human beings must eventually end up in environmental systems.

6. Conclusions

This study analyzed the life cycle environmental impacts of the materials phase of a net-zero energy building. It is important to identify those materials within the building system that have the greatest effect on a building's environmental impacts in order to target specific areas for minimizing environmental impacts in future construction. As more building are designed to meet net-zero energy goals, the embodied energy of the materials plays an increasingly important role which has never been calculated or taken into account. Many studies in the past have largely focused on use phase energy, as that building life cycle phase typically dominated analyses. We now need to reconsider the important interplay between building materials and use phase performance to truly design and operate net-zero energy buildings. An important and necessary aspect of "net-zero energy" designation is the quantification of embodied energy, illustrated via this case study and using life cycle assessment. Life cycle assessment is a necessary aspect to net-zero energy buildings to understand how the embodied energy of materials is allocated during a building's use phase.

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