

Embodied Energy Calculation and Reduction Strategies in Residential Buildings: A Case Study Approach

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Abstract—Embodied energy refers to the total energy used in the extraction, processing, manufacturing, transportation, and assembly of building materials, excluding the energy used during a building’s operation. As the construction sector significantly contributes to global energy consumption and greenhouse gas emissions, understanding and minimising embodied energy is essential for reducing the overall carbon footprint of buildings. With the increasing demand for new buildings in India, especially for the economically weaker sections, evaluating embodied energy is vital to reducing environmental impact. It highlights that as buildings become more energy-efficient during operation, embodied energy constitutes a larger share of their total life cycle energy. Strategies to reduce embodied energy include using recycled and locally sourced materials, modular construction, adaptive reuse, and integrating life cycle assessment (LCA) in the design phase.

Index Terms— Alternative Materials, Embodied Energy, Life Cycle Assessment, Sustainable Construction

I. INTRODUCTION

Embodied energy refers to the total energy consumed throughout the entire lifecycle of a building material. This includes energy used during the extraction of raw materials, their processing and manufacturing, transportation to the construction site, installation, ongoing maintenance, and ultimately their demolition, disposal, or recycling at the end of a building's life. It is often described as the "hidden" or "locked-in" energy because it is expended before the material becomes part of a completed building. This concept fundamentally differs from operational energy, which covers the energy required to run a building during its useful life, such as energy used for heating, cooling, ventilation, lighting, and appliances. At the same time,

operational energy has traditionally been the focus of energy efficiency efforts.

TYPE	DESCRIPTION	EXAMPLE
Extraction	Getting raw materials	Mining limestone
Manufacturing	Turning raw materials into products	Cement kiln operations
Transportation	Moving materials to the site	Diesel trucks
Construction	Building process	Cranes, mixers, tools
Maintenance	Upkeep and replacements	Repainting walls
Demolition	Taking down the structure	Excavators, breakers
Recycling	Post-use processing	Crushing concrete for aggregate

As buildings become more energy-efficient in operation, the relative importance of embodied energy increases, sometimes accounting for a significant portion of a building’s total life cycle energy use. Therefore, considering embodied energy is crucial for sustainable building practices, helping architects, engineers, and policymakers to minimise environmental impacts by making informed choices about materials, design strategies, and construction techniques. The idea gained traction in ecological science, industrial ecology, and architecture in the 1980s and 1990s, eventually becoming a foundational concept in Life Cycle Assessment (LCA)—a standard method for evaluating environmental impacts.

II. LITERATURE REVIEW

Reshma Kassim, M. Helen Santhi “Basic studies on embodied energy in construction materials”, (2016)- Abstract: One of the fastest-growing industries in India is the construction industry, which consumes significant energy. Construction materials are used in buildings, requiring a lot of energy during production. The total energy consumed by the construction materials can be reduced by selecting materials with low embodied energy. This paper assesses the indirect initial embodied energy of commonly used construction materials.

Keywords: initial embodied energy, OPC, PPC, burnt clay brick, sand, aggregate, quarry dust.

Material-Specific Studies –

Dixit, M. K., et al. (2012). “Need for Embodied Energy and Carbon Data in Building Material Selection: A Review.” This review focuses on specific materials like concrete, steel, and timber, analysing their embodied energy profiles and discussing their implications for sustainable building practices.

Design and Construction Practices –

Chou, J. S., et al. (2015). “Embodied Energy in Building Design and Construction: A Review of Strategies.” This paper examines various design strategies and construction practices that can reduce embodied energy, including material selection, recycling, and innovative construction methods.

Case Studies and Practical Applications –

Pomponi, F., & Moncaster, A. M. (2017). “Embodied Carbon Mitigation and the Role of Embodied Energy in Building Design: A Review of Case Studies.” This study provides insights from real-world case studies that highlight effective strategies for reducing embodied energy in building projects.

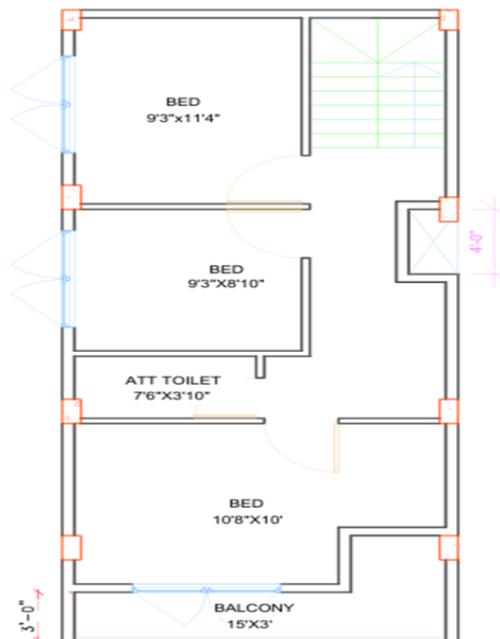
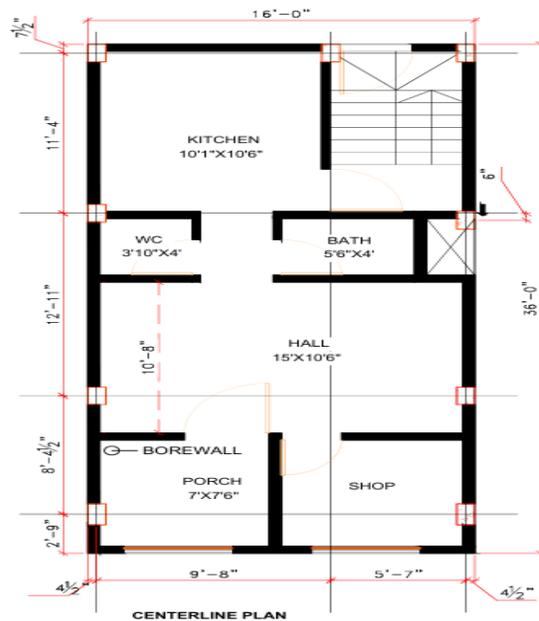
Regulatory and Policy Aspects –

Zuo, J., & Zhao, Z. (2014). “Green Building and Embodied Energy: A Review of International Standards and Policy.” This paper reviews international standards and policies related to embodied energy and green building certification, discussing how regulations influence construction practices.

Future Trends and Emerging Research –

Zhang, Y., et al. (2020). “Advancements in Low Embodied Energy Materials and Technologies.” This literature review looks at recent advancements in materials and technologies aimed at reducing embodied energy, highlighting innovative approaches and future research directions.

III. RESIDENTIAL BUILDING PLAN



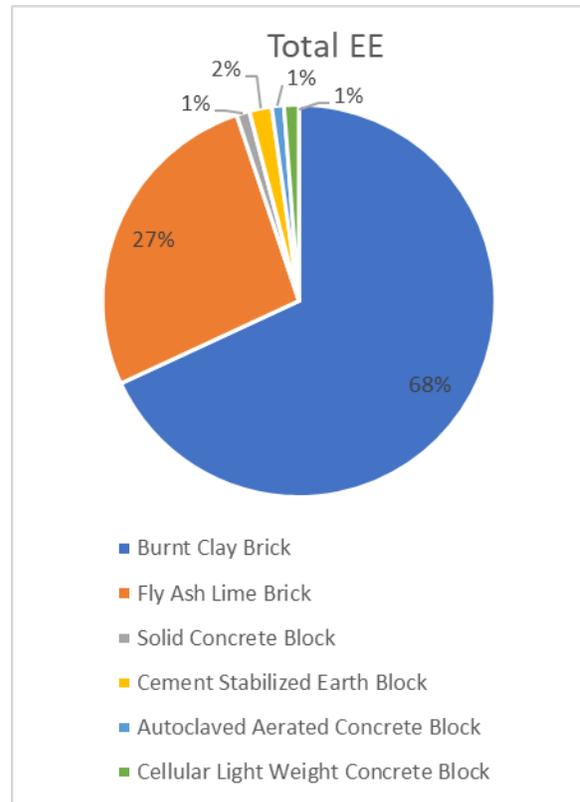
IV. CALCULATIONS OF EMBODIED ENERGY OF CONVENTIONAL MATERIALS

Sr. No.	Material Name	EE (mj/kg)	Material Quantity (kg)	Total Embodied Energy
1	Cement	7.36	686000	5048960
2	Sand	0.11	266880	29356.8
3	Aggregate (up to 20 mm)	0.2	119340	23868
4	Concrete	9	95930	863370
5	Brick	2.92	110592	322928.64
6	Reinforcement Steel	8.08	3301.01	26672.161
7	M. S. Grill	20	472	9440
8	Hard Wood	26.9	17.1	459.99
9	Glass	28.5	2.33	66.405
10	Vitrified Tiles	8.2	11800	96760
11	Ceramics Tiles	18.9	3330	62937
12	Paint	124	305790	37917960
TOTAL EMBODIED ENERGY				44402779.0

V. CALCULATIONS OF EMBODIED ENERGY OF ALTERNATIVE MATERIALS

Alternative Materials	Size	TOTAL EE (MJ/KG)
Burnt Clay Brick	230x110x75	322928.64
Fly Ash Lime Brick	230x110x75	126951
Solid Concrete Block	300x200x200	5078.04
Cement Stabilized Earth Block	230x190x100	8771.16
Autoclaved Aerated Concrete Block	600x200x200	4731.81
Cellular Light Weight Concrete Block	400x200x200	5816.67

MATERIALS



VI. CALCULATION OF PERCENTAGE REDUCTION IN EMBODIED ENERGY

Alternative Materials	EE (MJ/KG)	% Energy Reduction
Burnt Clay Brick	2.92	0.0
Fly Ash Lime Brick	1	66
Solid Concrete Block	1.25	57
Cement Stabilized Earth Block	0.5	83
Autoclaved Aerated Concrete Block	1.5	48
Cellular Lightweight Concrete Block	1.2	59

VII. CONCLUSION

In this paper, the embodied energy demand for a residential building is analyzed with existing conventional and alternative materials.

Embodied energy of the building materials depends on the type of manufacturing process and transportation distance, along with topography.

For this Residential Building, the total Embodied Energy of Brick is around 322928.64 MJ/kg, but if we use other Bricks, then its embodied energy reduces rapidly, making it more convenient.

The Embodied Energy of a Residential Building Constructed with cement-stabilized earth Blocks (CSEB) is lower than that of other alternatives. This is due to the non-requirement of any burning energy during their production, and also due to the fact that very little cement (8%) is required in the preparation. It is explored that the maximum possible Embodied Energy reduction is up to 80% by using Cement Stabilized Earth Blocks (CSEB).

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REFERENCES

- [1] Francesco Asdrubali, Gianluca Grazieschi, Marta Roncone, Corrado Carbonaro, Francesca Thiebat, "Sustainability of Building Materials: Embodied Energy and Embodied Carbon of Masonry", (2023).
- [2] Devadas Manoharan P, Muneeswaran Govindaraj, "Embodied Energy Assessment of Residential Building Using Conventional and Alternative Materials", (2018).
- [3] Reshma Kassim, M. Helen Santhi "Basic studies on embodied energy in construction materials", (2016).
- [4] Abhijeet D. Patil, Dr. A.C. Attar, "Automation of Embodied Energy Estimation Using Programming Tool", (2016).
- [5] Naveen Kishore, "Embodied Energy Assessment and Comparisons for a Residential Building Using Conventional and Alternative Materials in Indian Context", (2014).
- [6] Manish K. Dixit, Jose L. Fernández-Solís, Sarel Lavy, Charles H. Culp, "Need for an embodied energy measurement protocol for buildings: A review paper", (2012).
- [7] Teresa E McGrath, Sreejith V. Nanukuttan, Muhammed Basheer, Adrian E. Long, "Embodied energy and carbon foot printing of concrete production and use", (2012).
- [8] Goggins, Jamie; Keane, Teresa; Kelly, Alan, "The assessment of embodied energy in typical reinforced concrete building structures in Ireland", (2010).
- [9] Ambrose, M. D. and Burn, S. "Embodied energy of pipe networks", (2005)
- [10] Aysen Ciravoglu, "A Research On Embodied Energy of Building Materials: Reflections On Turkey", (2005).