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# LIFE CYCLE ASSSESSMENT OF A BUILDING IN INDIA:ENVIRONMENTAL IMPACT STUDY

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ABSTRACT
Based on the present scenario, green house gas (GHG) emissions have taken a toll on the environment rising the global warming limits. About 40% of annual global GHG emissions are generated by buildings. To minimize this negative environmental impact life cycle assessment (LCA) is required to be introduced and utilized widely.
LCA is a tool used to guide decision-making for sustainable development and to examine the capability of product's environmental impacts, material, process, or activity. In this study , assessment of overall energy consumption, embodied energyof building materials and emissions of a building and its materials are analyzed. Incorporation of LCA is also reviewed in the different phases of a building like constructions, operation and disposal phase.
This paper shows an approach to conduct an Life Cycle environmental impact assessment of building. This study also reveals the inter-relating factors like Construction, Operational and maintenance phases of a building. It is observed that LCA when utilized as a common practice in India, then an environmental awareness develops in the construction field by achieving sustainability and consistency. Buildings with efficient operational life and better design with future renovation plans can add less to the GHG emissions. Therefore, it is highly effective to construct environmentally adapted buildings in countries like India.
Keywords: LCA; Life Cycle Environmental Impact Assessment; Building Materials; Embodied Energy; GHG Emissions.

## 1. Introduction

Indian construction industry is one among the most important in terms of using manpower and volume of materials to be produced (cement, brick, steel and different materials). Construction sector in India is answerable for major input of energy leading to the maximum share of greenhouse gas emissions (22%) into the atmosphere (Reddy and Jagadish, 2003).
Buildings have important environmental effects from its construction phase to demolition phase ; and uses energy throughout its life (from cradle to grave). in the recent years,impacts on environmental associated with buildings i.e.ozone layer depletion, global warming, greenhouse gas (GHG) emissions, waste accumulation, etc. are increasing rapidly. (Sharma et al., 2012). International Panel on Climate Change (2011b); and IEA, World energy statistics and balances (2019) have detailed that the building sector represents almost 40% of the essential energy utilization and 36% of the energy associated with $CO_2$ emission in the industrialized nations. Also, a lot of energy is consumed by buildings for warming and cooling purposes (Sharma et al., 2012). In the present Worldwide scenario , one-third of all primary energy is used for buildings and where as they are considered responsible for half of GHG emitted in the environment (Asif et al., 2007).
So, limiting the utilization of the conventional materials by consuming elective materials, technologies and methods can bring out a vision for significant energy minimization leading to decrease $CO_2$ emission (Reddy and Jagadish, 2003). Even in the study of Ramesh et al. (2010),it is discovered that it is basic for the building construction industry to accomplish maintainable improvement in the society. Sustainable advancement is seen as improvement with low environmental effect, alow cost and social additions. To accomplish the objectives of sustainability it is needed to embrace a mufti-

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disciplinary methodology covering various features, for example, saving energy , improved utilization of materials including water, reuse and reusing of materials and emissions/discharges control.
One of the best ways to solve this environmental issue is by implementing Life Cycle Assessment (LCA).LCA is one of the notable devices for breaking down the natural effects by an item through its whole life for example from acquirement of crude material to discarding it. LCA is pertinent for all the phases of building and discovering the significant adjustments to boost the performance of the building (Horne, Grant, & Verghese, 2009). Even ISO (2006a) defines LCA as an methodology to evaluate the likely environmental effects and resources utilized all through an item's life cycle, i.e., from crude material securing, by means of production and usage phases, to waste control that consists of disposal in additionto recycling. Some other specific factors important for analyzing the environmental impact of a building are embodied energy and total energy consumption. According toHu (2017) embodied energy is the total energy needed for the extraction, preparing, manufacturing, and conveyance of building materials to the structure site.All around the world, various examinations have analyzed the connection between the embodied energy (i.e., the energy used for the production of the building and the working energy of the structures inside the buildings' whole life cycle (Utama et al., 2008).
Thus, this paper aims to make a proper analysis and assessment of life cycle environmental impact of a building by reviewing all the important methods, techniques and factors.

## 1. Study on LCA

As described by Sharma et al. (2012), LCA is one of the notable tools utilized for the quantitative assessment of a material utilized, energy streams and environmental effects of that particular item. It is a precise and systematic way to deal and acquire the effect of every material, cycle methodology and item. LCA is the most suitable structure to identify ,evaluate and to quantify the data sources and the outputs, andalso to assess the possible environmental effects for the life cycle (cradle to grave). LCA methodological structure includes four phases, i.e. A. goal and scope definition; B.life cycle inventory analysis; C.life cycle impact assessment; and D.life cycle interpretation. With the assistance of this tool it is conceivable to survey and look at the effects of various building.Figure 1 shows the different methodological frameworks of LCA.

The goal and scope definition is the one which builds up the Functional unit, system boundaries, and quality criteria for inventory data. The life cycle inventory analysis (LCIA) manages the gathering the data and synthesis of records of data on actual material and energy consumption in different phases of the Product life cycle.

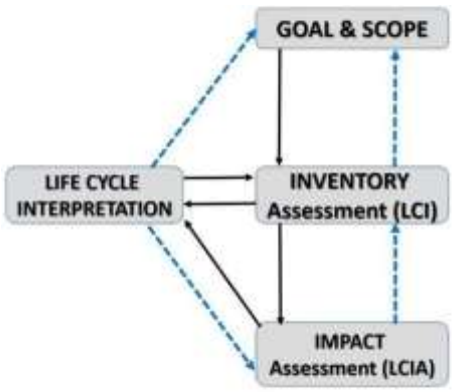


Figure 1: Framework of LCA (from IS/ISO 14044:2006)

In the life cycle impact assessment,different environmental impact categories are classified to assign the various environmental impacts depending upon the products material and energy utilized, where the characterization factor calculates constituents contribution based under various environmental indicators like GHG Emission, waste accumulation, etc. .

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At last, the LIFE CYCLE INTREPRETATION deals with the results from life cycle inventory analysis (LCI) and interprets with the result of life cycle impact assessment ,which includes incorporation of the recognizable issues and the assessment of results.
Moreover, LCA covers a variety of environmental effects and may incorporate balancing across impact Categories. It can accordingly be contended that demonstration to be conducted preferably with a similar level of authenticity for each impact and to exclude nonessential comparison between categories. On this foundation, LCA focuses on a comparable method of surveying impacts. (Finnveden et al., 2009).
Buildings usually obtain energy immediately or in a roundabout way in all periods of their life cycle directly from the cradle to the grave and there is interaction between stages of energy use (embodied energy and operating energy). Consequently, they should be analyzed from life cycles perspective.(Ramesh et al., 2010). According to the EN 15978 (2011) standard,According to the EN 15978 (2011) standard, the life cycle stages for a building include (A)Product stage - collecting raw materials , transport to manufacturing site, and assembling), (B) construction stage- (transport to building site, and development), (C) Usage stage- (emissions during use, maintenance, repair, replacement, refurbishment, operational energy and water use), and (D) Demolition stage- (deconstruction/destruction, shipping wastes for recycling or to disposal sites, waste processing, and disposal)(Nwodo and Anumba, 2019). Thus in the study of Ramesh et al. (2010), it is clearly seen that the impact of various stages of the structure on climate is like sharing the energy proportion of these stages in the life cycle energy of the Product. LCA considerably rely on the essential sources of the energy of a specific location and change proficiency of materials manufacturing process.
LCA is thus no substitute for (Environmental) Risk Assessment as shown by Finnveden et al. (2009). Although , the outcomes from the LCIA shows the expected commitments to definite impacts and legitimacy of the reference conditions accepted in the models given below (Olsen et al., 2001; Hauschild, 2005; Tiruta-Barna et al., 2007).

## 1. Methodology

In this paper, the study aims to show an approach to conduct an Life Cycle environmental impact assessment of building, by reviewing some important factors like embodied energy , total energy consumption and GHG emissions .
LCA itself is a methodology that has 3 significant types.These three types of LCA methodology :

1. Process based LCA: Assessing the environmental weights of an item, cycle, or assistant can be a massive assignment. An underlying way to deal with finishing a life cycle assessment is a Process based LCA method. In this, the input (materials and energy resources) and the outcome (emanations and squanders to the climate) are gathered for a given advance in developing a structure.
2. Input-output LCA:The Input-Output Life Cycle Assessment (IO-LCA) technique calculates the materials and energy assets required, and the environmental emissions coming out of the product life cycle.
3. Hybrid LCA: This method is a combination of both process based and IO-LCA . The life cycle of the building is divided into three main phases (Sharma et al., 2012):

a) In Construction phase , the constructive material from the inventory considered and their corresponding embodied energies are being calculated.
b) The Operation phase of a building is thought to be 50 years. The assessed environmental impact during this stage depends on the presumption that no expansions and re-development are made during the long term life cycle(i.e no maintenance). The effect of this stage has been assessed by methods for its energy use.

a. In Maintenance phase, just successive support, for example re-painting has been considered, just 2% of absolute energy utilized is considered according to the standard practice.

In the study by Sharma et al. (2012), the process based LCA has been considered. Here, the user traces all cycles related with all life-cycle periods of an item, and respected inputs and outputs with each cycle, by which complete environmental burden energy can be resolved.

The building materials used for constructing a building will have significant contribution to the emissions from the building that effect the environment in return. The embodied energy of each and every building material is determined and calculated correspondingly.
Embodied energy (EE) of building materials comprises the total energy utilized for production of building materials which includes basic material extraction and related transportation.according to Sharma et al., 2012 the energy consumed in extraction, manufacturing, assembly and transportation of a particular product (I.e energy from cradle to grave) is embodied energy . Similarly Reddy and Jagadish (2003) has dealt with different aspects of embodied energy, which are (1) energy utilized during the manufacturing primary building materials, (2) energy required during transportation of these product, and (3) energy needed for fabricate these materials to shape the building.

However, in the study by Ramesh et al. (2010) and Bribian et al. (2011) embodied energy is being divided in two parts: initial embodied energy and recurring embodied energy. Here, the initial embodied energy is the energy needed for construction of building in the partial phase; whereas the recurring embodied energy is the total energy used in the rehabilitation and maintenance of the building .As Sharma et al. (2012) has described, the embodied energy of a building material can be determined by equation (1) :
Total embodied energy (MJpri) = Standard Embodied Energy(MJ/m3) x Volume(m3) (1)
The value of the above mentioned Standard Embodied Energy (MJ/m3) of all the different kinds of building materials are calculated and well explained in the paper by (Reddy and Jagadish, 2003).
With the help of this embodied energy , the total life cycle energy of the building can be estimated . Like Fay et al. (2000) has mentioned that life cycle energy comprises the operational energy of the building and its initial and recurrent embodied energy - life cycle energy involves the operational energy of the building and its initial and recurrent embodied energy over its expected lifetime.
Life-cycle energy was calculated using the equation (2):
LCE = EEi + (EErec + OE) × building lifetime (2) Where,
LCE = life-cycle energy;
EEi = initial embodied energy of building; EErec = the annual recurrent embodied energy (for example, in maintenance); and
OE = the annual operational energy (including space conditioning and other domestic energy uses).
Operational energy (OE) is the energy needed for keeping up comfort conditions and everyday maintenance of the structures (Reddy and Jagadish, 2003).
The above obtained value of the total life cycle energy is utilized to determine the life cycle GHG emissions from the building . This concept is clearly explained in the paper Sharma et al. (2012) using the equation (3) shown below :
Life cycle GHG emissions = Total life cycle energy (pri) × Conversion factor for primary to electrical × average emission coefficient (3)

Sharma et al. (2012) has estimated this energy related to the electricity by gathering power bills for last 2–3 years and dependent on these bills normal yearly power utilization is 34,800 kWhe. The transformation of essential energy (thermal) into power is taken as (1 MJpri = 0.111 kWhe). The he total average electricity consumption for 50 years is 1.74 GWhe; and the normal power change productivity from thermal energy has been taken as 0.40.

## 2. Evaluation and discussion

Hu (2017) has clearly mentioned that in all life cycle phases the energy and materials demand will be determined first and then the results of the other selected impact .The historic building which had been

used as a case study by Hu (2017), the life span was found to be 75 years and the operational energy was more than min 55% in all different aspects.Based on the finding it was found that the new construction had a much higher environmental impact from the product stage to end of life . If demolition is avoided then 48% deduction in overall environmental impact would be done
Utilization of energy proficient elective building innovations can bring about impressive decrease in the embodied energy of the structures (Reddy and Jagadish, 2003).
The connection between operating energy and life cycle energy of the building is directly proportional with the climatic and different contrasts. There is likewise an unmistakable differentiation between the existence cycle energy utilization of private and places of business because of the higher epitomized and operating energy of places of business when contrasted with residential/private ones. It could be credited
to the way that places of business are for the most part multi-storey cement or steel structures, requiring high embodied energy than wood structures of private structures. Operating energy is likewise more because of high inhabitable condition, requiring more energy to keep up comfort conditions inside the structure. Furthermore, electrical energy needed for lighting and to control apparatuses is additionally enormous on the grounds that they exist in huge numbers contrasted with private houses. Every one of these elements add to higher life cycle energy of the places of business when contrasted with residential ones (Ramesh et al., 2010).
Low energy building are the structures having explicit plan that request less operating and life cycle energy than if worked by traditional conditions. (Sartori and Hestnes, 2007). In any case, if there should be an occurrence of self-sufficient house, however its operating energy is zero, its embodied energy is high to such an extent that it surpassed life cycle energy of few low energy cases.
Ramesh et al. (2010) communicated a view that there is a cutoff to decrease in energy utilization for activity by energy escalated domestic engineering frameworks. In any case, these investigations didn't tell how much the energy use for activity can be diminished before the embodied energy will be high to the point that the absolute energy use during the life time will begin to increment once more. Also it is discovered that planned low energy structures perform in a way that is better than self-sufficient houses in life cycle setting
The impact observed in the paper by Bribian et al. (2011) was to be, in the medium term, between 20 -30% greater than the impact data obtained in other studies.
Chau et al. (2015)has demonstrated that the value of LCA can be additionally improved in building development by standardizing the needs for singular examinations/study on the limit perusing, methodology decisions and data inventories to set up benchmarks for various types of structures.

Additionally, it is critical to broaden the current extent of LCA to incorporate impacts of indoor environmental characteristics, building area just as social contemplations or it can apply the basic LCA idea to plan the structure environmental evaluation assessment grasping all of these perspectives.
The benefits of using LCA for a building has been well depicted by (Nwodo and Anumba, 2019) ; where LCA helps to give a proper building material choice and their respective environmental impact to evaluate design operations (Simonen, 2014). A building can achieve Green Building Certification when LCA is used as a decision support tool in the process development and the construction of a building i.e LCA has the potential to determine whether the building is environmentally preferable or not (Hauschild et al., 2018; Simonen, 2014).
From a methodological viewpoint, the blend of IOA and LCA is promising to supplement LCA applications for full scale level strategy uphold. Recent exploration concentrates regarding IPP expanded the regions of LCA type applications, distinguishing which areas may have the maximum environmental impacts. (Finnveden et al., 2009)
Referring to the above mentioned equation (1) used by (Sharma et al., 2012) i.e :
Total embodied energy (MJpri) = Standard Embodied Energy(MJ/m3) x Volume(m3)

the following Table 1 has been obtained for all different types of building materials for its construction and processing by dividing the buildings life cycle into three main phases (construction; operation and maintenance).

Table 1 : Total life cycle energy usage for the building studied by (Sharma et al., 2012).

| Sl no. | Energy used in each phase | Total embodied energy (MJ) | Percentage (%) |
|---|---|---|---|
| 1. | Construction | 10,512,410.8 | 39.82 |
| 2. | Maintenance | 210,248.22 | 0.80 |
| 3. | Operation | 15,675,675.68 | 59.38 |
| **Total** | | **26,398,334.7** | **100** |

Again, similarly by using the equation (3) ie:

Life cycle GHG emissions = Total life cycle energy (pri) × Conversion factor for primary to electrical × average emission coefficient the value of the total life cycle GHG emissions obtained is 1764.82 Mg-CO2eq .

Conclusion

1) It is seen that the vast majority of the energy (59%) is burned-through during the utilization (operation) phase of the structure. Since the activity stage is prevailing and there is similarity between the energy utilization and the environmental effect

during the life cycle, it is better to incorporate both: design of structures that are energy-efficient during their occupation stage, and to create energy (electricity) with low emissions.

2) The new development has a lot higher environmental impact from the product stage to end of-life.

3) Use of energy proficient alternate building structure advances can bring about impressive decrease in the embodied energy of the structures.

4) Building's life cycle energy request can be decreased by diminishing its operating energy fundamentally if it leads to prompts a slight expansion in embodied energy. It is additionally seen that low energy structures perform in a way that is better than self-sufficient structure in life cycle setting.

5) LCA gives a precise data on the impact of every item, which would encourage a right assessment of the effect of a structure. Without this data, this effect must be assessed around utilizing existing inventories which are hard to adopt to the reality of a particular topographical region.

6) To expand the convenience of building LCA for decision making, a multi-target assessment along with other assessment techniques and tools are required.

7) Development and utilization of LCA has been stronger for the last few years. These include a better understanding of the difference among all the methods of LCA like process based LCA, input-output LCA (IO-LCA), methods for hybrid LCA and better models for impact assessment.

8) Important factors like embodied energy, operational energy, total life cycle energy, GHG emissions and building materials are all required for implementing LCA properly on a building.

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