# Life Cycle Assessment towards Environment Friendly Building

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***Abstract - Various management tools and structural designs to evaluate environmental concerns are available and Life-Cycle Assessment (LCA) is one of the best tools to achieve sustainable building practices. By applying LCA it is possible to optimize these aspects, from the extraction of raw materials to the final disposal of waste building materials. LCA examines environmental inputs and outputs related to a product or service life-cycle from raw material extraction, through manufacture, usage phase, reprocessing where needed, to the final disposal. And design structure accordingly to achieve 100% efficiency towards balancing environmental needs. This paper deals with the LCA methodology of environment-friendly building and structure design (residential, commercial building) which greatly reduced energy needs through efficiency gains such that the balance of energy needs can be supplied with renewable technologies is discussed and reviewed as a means of evaluating its impact.***

***Keywords - Life cycle assessment Tool, LCA Methodology, Environment Friendly, Structure Design, Energy Reduction, Efficiency Gain, Renewable Technology, Building.***

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## 1. INTRODUCTION

Environmental awareness in building design, construction, and operation, materials is stronger than ever. how might we meet the world's quickly developing requirement for building and still be environmentally responsible? Although construction is never fully mild for the environment, designers and builders can make choices to minimize the impacts. So that it can stop building's stress on the planet. also, depletion of natural resources, ecosystem disruption, air and water pollution, and generation of waste are just some of the undesirable side effects of building construction and operation will minimize. Atmospheric carbon dioxide (CO2) is currently the most important contributor to the greenhouse effect and climate change will reduce. These issues must be addressed by professionals in the construction industry in order to satisfy their own social consciences — as well as home buyers' concerns and ecofriendly development.

Environmental development requires methods and tools to measure and compare the environmental impacts of human activities. Environmental impacts include those from emissions into the environment and through the consumption of resources, also as other interventions (e.g., land use) related to providing products that occur when extracting resources of product, the material used during production, product manufacturing, during consumption, and at the end of products' life (sorting, reuse, recycling, waste disposal). These emissions and consumptions lead to many different environmental consequences, including climate change, stratospheric ozone depletion, tropospheric ozone (smog) formation, eutrophication, acidification, toxicological stress on human health and ecosystems, resource depletion, water use, land use, and noise among others. A clear need, therefore, exists to be proactive and to provide complementary insights, apart from current regulatory practices, to help reduce such impacts.

High-performance homes, especially those striving to achieve total natural execution, utilize various energy proficient materials and development practices that need to be integrated into the earliest phases of design. Customarily designers and architects may not specify certain efficient methods-related details or may neglect to make certain decisions relating to energy performance strategies during the design phase, resulting in added costs for builders. For meeting the environment successfully, architects and designers, together with their builders, should familiarize themselves with the 12 Steps to costeffective environment-friendly home construction and pay special attention to the design strategies, and their details on the construction plans as needed. Attending to these energy performance details at the planning stage will keep construction costs low.

### 1.1 Life cycle assessment

LCA is a methodological framework for estimating and assessing the environmental aspects attributable to the life cycle of a product. From the extraction of raw materials through the final disposal of waste building materials, LCA can be used to optimize various areas. LCA tool examines inputs and outputs of environment-related to service life cycle from cradle to grave, (i.e., from raw material extraction, through manufacture, usage phase, reprocessing where needed, to the final disposal.)

The fact that LCA is new to the construction sector is a major issue. As there are many misconceptions about LCA tools in any developing field, which can cause misuse of LCA tools, techniques, and corresponding data unintentionally. Thus, there is a requirement for a transparent working definition of LCA and related terminology to assist build credibility for the methodology and make the building industry more receptive to this unique way of assessing their work.

Various methods are available for the assessment of the environmental impacts of materials and different components within the building sector. The assessment includes the whole life cycle of a product, process system encompassing the extraction and processing of raw materials; manufacturing, transportation and distribution; use, reuse, maintenance, recycling, and final disposal [5,31].

The LCA methodology is from the 1960s when concerns over the limited availability of raw materials and energy resources led to new ways. within the early 1990s, LCA was used for external purposes, like marketing and its application broadened. This was mostly owing to the formalization of LCA standards as part of the ISO 14000 series (1997–2002) and, as a result, the introduction of the Life Cycle Initiative. The principles provided by ISO standards and SETAC are properly structured for industrial processes.

However, when LCA is applied to buildings, the following common differences need to be considered.

- The useful life of a building is typically much longer than for industrial products

- The uniqueness in the character of each building project differs from the many of identical products in industrial systems

- It is difficult the characterize the functional unit or boundary of analysis for a building, as compared to an industrial product.

As per these differences, it is clear that guidelines which are for industrial products cannot be borrowed directly for use in buildings. The use of the LCA in the building construction sector requires a bunch of guiding principles that considered the unique character of each building design, its complexity in defining systems, and related decisions made by the owner and design team [1-26-28]

Because LCA is a relatively new concept in the construction industry, there is a considerable risk of misapplication of LCA tools, procedures, and supporting data. As a result, a precise operational definition of LCA and related concepts is required to assist develop credibility for the technique and make the construction sector more amenable to this new form of work evaluation. LCA includes the collection and evaluation of quantitative data on the inputs and outputs of material, energy, and waste flow associated with a product life cycle [26-30].

### 1.2 Life cycle stages

Materials Manufacturing: The removal of raw materials from the ground, transportation of materials to manufacturing facilities, manufacture of finished or intermediate materials, and construction are the stages of a building's life cycle. product fabrication its's packaging, and distribution of building products used in Construction. All activities relating to the actual building construction, its Use, and Maintenance. Building operation includes energy consumption, water usage, generation of waste from the environment, repair and replacement of building assemblies and systems, transport and equipment used for repair and replacement energy consumed, and waste produced due to building demolition and disposal of materials to landfills, and transport of waste materials are included at the end of life. Recycling and reuse activities related to decayed waste also can be included and have a “negative impact”.

- LCA for the different assessment criteria of building construction can be done by using LCA software tools collectively or it can be done separately.
- Firstly, LCA concepts and focuses on the LCA methodology and tools employed in the built environment.
- Secondly, this study should outline and discusses the differences between the LCA of building materials and components combinations versus the LCA of the full building life cycle.
- At last, this work can be used by stakeholders because an important reference on the LCA tool includes up-to-date literature on approaches and various

methods to conserve the environment and therefore gain sustainable development.

The scope of LCA can reach various stages and processes during a product's life. Depending on the aim of conducting the LCA, one among two primary means for conducting the LCA is often considered. The two primary versions of LCA are process-based LCA and Economic Input-Output based LCA. Within each variant there exist a number of options to be considered. Within each variant there exist a number of options to be considered.

## 2. LITERATURE REVIEW ABOUT BUILDING MATERIALS AND COMPONENT COMBINATIONS (BMCC)

The LCA calculations should assess all materials, as some materials used in very small quantities have large environmental impacts [6]. Many industrialized countries have taken steps to enhance the environmental aspects of the construction process, building occupation, and destruction, but these steps varied in the degree to which building construction is heavily influenced by local traditions, climate, and natural resources. In India, research of embodied energy in load-bearing masonry buildings was conducted in 2001. A brickwork building and a soil–cement block building was compared, and the study showed that the total embodied energy can be reduced by 50% when energy-efficient building materials are used [16].

Another study of flooring material in Italy showed that marble tiles are more environmentally friendly than ceramic tiles [17]. In Finland, Seppala et al. As part of the Finnish Environmental Cluster Research Programmed 1998–2000, a Life-cycle Inventory (LCI) of steel plate and coil, steel bar, steel wire, stainless steel, copper, nickel, zinc, and aluminum was created [18]. The primary energy input (mainly fossil fuels) in the production of materials was found to be about 60-80% higher when concrete frames were considered instead of timber frames [19]. The timber and concrete designs analysis of the same building in terms of its embodied energy using an input-output based hybrid framework instead of the process analysis Borjesson used [10]. Their estimations of energy requirements and greenhouse gas emissions were double [10]. Considered production scenarios, the materials of the timber-framed building had lower energy and CO2 balances than those of the concrete-framed building in all cases but one [20]. A steel-framed office building in China with a concrete-framed one is compared by [21]. The steel-framed building's life-cycle energy consumption of building materials per area is 24.9 percent that of the concrete-framed building, however the energy consumption and emissions of the steel-framed building are both higher than those of the concrete-framed building in the usage phase. As a result, the energy consumption and environmental emissions achieved by the concrete-framed building over its whole life-cycle is lower than the steel-framed one [21].

The CO2 emissions of eight different building materials for a home in Scotland are calculated: wood, concrete, glass, aluminum, slate, ceramic tiles, plasterboard, damp course, and mortar by [14]. The study concluded that 61% of the embodied energy used in the house was related to concrete. Timber and ceramic tiles come next with 14% and 15%, respectively, of the total embodied energy. Concrete was responsible for 99% of the total of CO2 emissions of the home construction, mainly due to its production process [14]. Process analysis, input-output data calculation, and hybrid analysis were all employed to calculate the embodied energy in BMCCs.

## 3. LCA METHODOLOGY

LCA is defined by ISO 14040 as a technique for assessing the social, environmental aspects and potential consequences of a product by collecting an inventory of relevant inputs and outputs of a product system, which involves evaluating potential environmental impacts and reflecting the results of the inventory analysis and impact assessment phases. LCA is often employed as an analytical decision support tool [2]. The methodology of LCA is based on ISO 14040 and it consists of mainly four distinct analytical steps: Defining the goal and scope, creating the life-cycle inventory, assessing the impact and finally interpreting the results (Fig.1).

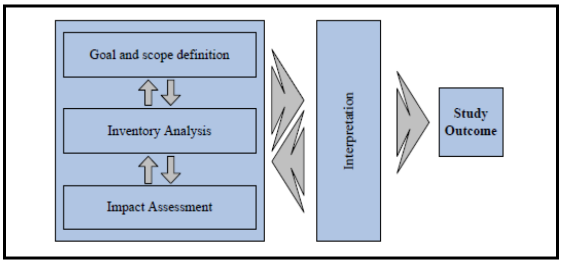


**Fig.1: Life cycle assessment framework [3]**

The International Standards Organization ISO:

- ISO 14040 Environmental management, LCA, Principles, and framework (1997).
- ISO 14041 Environmental management, LCA, mission, meaning, and inventory analysis (1998).
- ISO 14042 Environmental management, LCA (2000).
- ISO 14043 Environmental management, LCA, Life-cycle interpretation of tool (2000).

**Step 1: goal and scope**

The goal and scope definition of an LCA provides a description of the production system in terms of the system boundaries and a functional unit. The functional unit is the important basis that enables alternatives, to be compared and analyzed. The goal of LCA in the construction of buildings is to minimize the environmental burdens over the whole life cycle [5]. The description of LCA is the function of the building and the geographical location of the building, and other technical features (6). The research's system boundaries should be clearly defined, including whether the study will include the entire building life cycle or just one phase; the entire building or just one system; and the environmental effect categories to be studied. Within this step, consideration should be given to the functional unit, methodologies of impact assessment, data requirements, assumptions, limitations, initial data quality requirements, type of critical review, and type of the report required for the study [4].

1. Objectives
2. Limitations
3. Constraints
4. Important assumptions
5. Identifications of system boundaries such as,
    a. The full lifetime of a product
    b. Functional unit

**Step 2: inventory analysis**

Inventory analysis is second step of the LCA. It contains data collection and calculation procedures [3,13]. All data linked to energy input-output and mass flow in terms of quantities and emissions to air, water, and land are included in the data collection. The life cycle of a building consists of a minimum of three phases starting with the pre-construction phase, which includes all the processes from materials extraction up to the start of building occupation, followed by the usage phase, and ending with the demolition phase, but each of these phases could be divided into many sub-phases according to the goal and scope of the study.

The quality of inventory data, its correctness, and its conformity with the study's purpose are all closely related to the quality of life-cycle assessment. The source of data might be one or more direct measurements, laboratory measurements, governmental and industrial documents, trade reports and databases, national databases, environmental inventories, consultancies, academic sources, and engineering judgments. Three other indicators related to the correlation between the data and the data quality goals, namely temporal correlation, geographical correlation, and technological correlation.

Due to the wide range of materials in the construction industry, and the variety of construction techniques, none of the available tools and data sets is able to model or compute the environmental impacts of a whole building or construction, including all the life-cycle phases and production processes in detail [7 - 13]. The databases and tools vary according to study goal, users, application, data, and geographical location. Databases differ from one country or region to another according to many factors, including energy sources, supply assumptions, product specifications, manufacturing differences, and complications in economic activities.

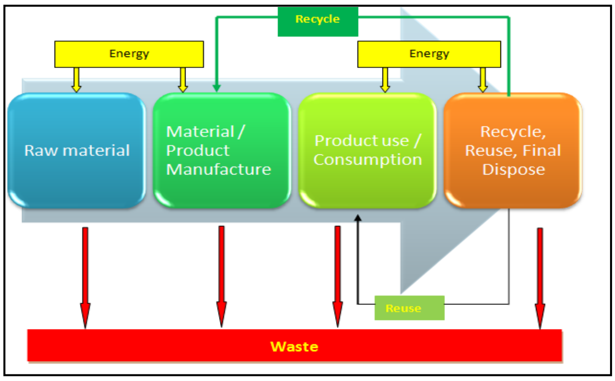


**Fig.2. Simplified procedure for inventory analysis [13]**

**Step 3: impact assessment**

The international standard for life-cycle impact assessment (LCIA) is ISO 14042, which states that the goal of the assessment is to - Examine the product system from an environmental standpoint using impact categories and category indicators linked to the LCI results [14,15]. The impact assessment framework is a multi-step process that begins with the selection and definition of impact categories that are relevant to the structures (such as global warming, acidification, toxicity, etc.)

**Step 4: Interpretation**

The need for and potential to lessen the impact of the product(s) or service(s) on the environment are carefully analysed, and the LCA results are provided in the most informative way feasible. In this step, the results are often presented in the form of tables or graphs, which is especially helpful when comparing two competing design options or products. This step's result is directly applicable to making ecologically friendly decisions. The interpretation of the LCA, like any other design feedback tool, might lead to changes in the suggested design, which goes back to Step 2 in the process [3].

**3.2 Economic input-output based LCA method**

The Economic Input-Output Life Cycle Assessment (EIO-LCA) technique calculates the materials and energy resources required for a given economy's operations, as well as the environmental emissions produced by those activities. Unlike process-based

LCA methods, which focus on a particular process in-depth, input-output-based LCA methods evaluate the entire economy—all activities across all industry sectors. Although this type of study provides a more comprehensive picture of a process or product's influence, it is based on sector-level averages that may or may not adequately represent a subset of the sector relevant to A Guide to Life Cycle Assessment of Buildings a specific product. The EIO-LCA method is not acceptable for use in the construction sector to determine whether certain actions are ecologically beneficial or damaging within a project [3]. The EIO-LCA method is more suited to estimating the total impact of a single component on the whole construction sector, such as the use of fly ash in concrete.

## 4. LCA TOOL/ SOFTWARE

Many different computer programs are available that estimate operating energy in buildings.

The "Quick Energy Simulation Tool" (eQUEST) is widely used for comprehensive and detailed output of monthly and annual energy use of the buildings. Also, it permits a detailed description of a building's geometry, layout, envelope, operating schedule, space conditioning systems (such as HVAC and lighting), climatic data, and much more.

In North America, the ATHENA- EIE for Buildings is the only software tool currently available. The ATHENA is Environmental Impact Estimator (ATHENA - EIE) for Buildings v4.0.64 and can be used to assess the material and energy inputs and outputs if available. In India, SIMA PRO is released in 1990. This is a reliable and flexible tool, used as LCA software worldwide, and is used for the assessment of products, processes, and services as per the ISO 14040 series. Over 11,000 inventory data records can be done by using SIMA PRO.

## 5. SUMMARIZED CONCLUSION

Study of the environmental benefits of using recycled, reused, or recyclable, reusable materials in the building industry, is very important for advancing sustainable development, because of the embodied energy and environmental effects they count, and therefore their proposed suggestions to scale back the environmental pressure of buildings, through the manufacture, and transport of varied materials. also, another note is that these studies might be considered as data inventories, or benchmarks when undertaking an entire building LCA tool. The main effort of the LCA is in the inventory analysis, where materials and activities are analyzed and the emissions from them are accrued. The environmental impact of these emissions can be analyzed using a recognized method for impact analysis.

The LCA can be done by preparing and using different impact assessments methods for different criteria like Site planning, Total water management, Energy conservation, Eco-friendly and energy-efficient building materials, Renewable energy, and Solid waste management. Moreover, the systematic approach can be applied to the whole project at a different hierarchical level in the project life cycle from material extraction to demolition and disposal.

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