ABSTRACT

The environmental performance of products and processes has become a key issue. Many construction companies have found it advantageous to explore ways of moving beyond compliance using pollution prevention strategies and environmental management systems to improve their environmental performance. One such tool is LCA. Although LCA has been widely used in the building sector since 1990, and is an important tool for assessing buildings, it is less developed than in other industries, including perhaps the engineering and infrastructure sector. The concept of LCA considers the entire life cycle of a product. Applying LCA in the building sector has become a distinct working area within LCA practice. LCA practice in the building industry has taken place at a national level, but in general much scope remains for wider involvement and cooperation. This research aims to bridge this gap by assessing the life cycle impacts of the building. The purpose of this study was to develop the model to estimate the CO2-emissions of building according to Indian condition.

Keywords—carbon footprint, LCA Model, Building LCA.

II. METHODOLOGY

LCA is one of the available methodologies for assessing the environmental impacts related to product systems. Life Cycle Assessment (LCA) is relatively new to the building industry. LCA heightened awareness of the importance of environmental protection, and the possible impacts associated with building products. Thus, there exist great confusion about LCA, which can inadvertently lead to misuse of LCA tools, techniques, and supporting data. Thus, there is a need for a clear working definition of LCA and related terminology to help build credibility for the methodology and make the building industry more receptive to this new way of evaluating their work. This study provides the information to aid in basic understanding of LCA concept and its application.

In order to make LCA a workable tool for comparative purposes, the first step required is to establish a standard technical framework and terminology. It is this task that ISO has taken upon itself. The ISO framework consists of the following phases: Goal and scope
definition, Inventory analysis, Impact assessment, and Interpretation. Figure 1 represents the link between these components. As can be seen from the Figure1, LCA is not a linear process that simply starts with the first and ends with the last phase. Instead it often follows an iterative procedure, at increasing levels of detail. The individual phases of an LCA will be described below. The standardization of these phases is laid down in the new ISO 14044 standard.

Phase One: Goal and Scope Definition
An LCA starts with an explicit statement of the goal and scope of the study, which sets out the context of the study and explains how and to whom the results are to be communicated. In this phase, the goal and scope definition is designed to obtain the required specifications for the LCA study. The scope describes the system and marks which information is necessary, in what categories, and the level of detail and quality [1]. Goal and Scope includes:

- The functional unit, which defines what precisely is being studied and quantifies the service delivered by the product system, providing a reference to which the inputs and outputs can be related
- The system boundaries;
- Any assumptions and limitations;
- The allocation methods used to partition the environmental load of a process when several products or functions share the same process; and
- The impact categories chosen

The functional unit is used as a basis for calculation and usually also as a basis for comparison between different systems fulfilling the same function [2]. It means that all data collected are quantitatively related to one quantitative output of the product.

Phase Two: Inventory Analysis
Inventory Analysis involves data collection and calculation procedures to quantify relevant inputs and outputs of a product system. The Inventory Analysis phase consists of data collection, refining of the system boundaries, involves calculation, allocation and relation of data to the specific system, as well as a validation of the applied data. The data must be related to the functional unit defined in the goal and scope definition. Data can be presented in tables. Refining the system boundaries has to be carried out carefully and in consideration of the defined scope of the study, and shall result in a limitation of data handling to those input and output data that are significant for the goal of the study. The results of the inventory is an LCI which provides information about all inputs and outputs in the form of elementary flow to and from the environment from all the unit processes involved. Data will then be aggregated in order to result in an input-output table for the product or service.

Phase Three: Impact Assessment
Inventory analysis is followed by impact assessment. Impact Assessment phase “is aimed at evaluating the significance of potential environmental impacts using the results of the Inventory Analysis” (ISO 14040). Life cycle impact assessment (LCIA) consists of the following mandatory elements:

- selection of impact categories, category indicators, and characterization models;
- the classification stage, where the inventory parameters are sorted and assigned to specific impact categories; and
- Impact measurement, where the categorized LCI flows is characterized, using one of many possible LCIA methodologies, into common equivalence units that are then summed to provide an overall impact category total.

Phase Four: Interpretation
Life Cycle Interpretation is a systematic technique to identify, quantify, check, and evaluate information from the results of the life cycle inventory and/or the life cycle impact assessment. LCA results are reported in the most informative way possible and the need and opportunities to reduce the impact of the product(s) or service(s) on the environment are systematically evaluated. [UNEP2003]. 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. The outcome of the interpretation phase is a set of conclusions and recommendations. According to ISO 14040:2006, the interpretation should include:
The outcome of this step is directly useful in making environmentally friendly decisions. A key purpose of performing life cycle interpretation is to determine the level of confidence in the final results and communicate them in a complete and accurate manner.

III. OVERVIEW OF PREVIOUS WORK
IN THIS AREA

In recent years there have been a number of efforts to document the environmental impacts (including energy and carbon impacts) of different materials used in the building industry. Most of the results of these studies are incorporated in the comprehensive LCA databases for materials and processes currently used in commercial LCA applications (such as Sima Pro and Gabi4). In the UK, the Building Research Establishment’s (BRE) database of materials and their environmental impacts is published in the form of books such as the Green Guide to Specification[7], websites (www.greenbooklive.com) and tools (e.g. BREEM) and are widely used by academia and industry. The ‘Environmental profiles’ database for materials, produced by BRE, is based on process based LCAs of different UK construction materials in an effort to produce standardized environmental data on construction materials in the UK [7]. The precursor to embodied carbon studies, Life Cycle Energy Analysis (LCEA) has also become popular as an indicator of environmental performance. Initial publications on embodied energy coefficients of materials originate from the Buildings Research Association in New Zealand [8] [9] [10]. Current LCEA work in the UK includes the Inventory of Carbon and Energy (ICE) developed by the University of Bath’s Sustainable Energy Research Team [11] [12].

LCA Based Model: Building for Environmental and Economic Sustainability (BEES)

A process LCA model approach used in a large number of construction-related applications is Building for Environmental and Economic Sustainability (BEES), a software tool developed by the National Institute of Standards and Technology (NIST) to estimate the implications of materials selection in infrastructure planning, mostly for buildings [13]. The green building movement has fueled the growth and popularity of BEES, which provides economic and environmental data for 200+ building products (NIST 2007). BEES is based on manufacturer data, which can be unreliable and includes a certain amount of uncertainty. BEES is also material-based and does not include on-site construction processes, so its applicability to the hybrid LCA being created here is negligible.

BEES Methodology

- Economic performance measured using similar life cycle thinking
- Economic performance measured using ASTM standards life cycle cost method, which covers
  1. cost of initial investment
  2. Replacement
  3. Operation
  4. Maintenance, repair and disposal

BEES measures the environmental performance of building products using the internationally standardized and science-based life-cycle assessment approach [5]. All stages in the life of a product are analyzed: raw material acquisition, manufacture, transportation, installation, use, and recycling and waste management. Up to ten environmental impacts are measured across these life-cycle stages: global warming, acid rain, resource depletion, indoor air quality, solid waste, eutrophication (the unwanted addition of mineral nutrients to the soil and water), ecological toxicity, human toxicity, ozone depletion, and smog. Due to its comprehensive, multi-dimensional scope, life-cycle assessment accounts for shifts of environmental problems from one life-cycle stage to another or one environmental medium (land, air, or water) to another. The approach highlights the tradeoffs that must be made to genuinely reduce overall environmental impacts.

BEES measures economic performance using similar life-cycle thinking. Economic performance is measured using the ASTM standard life-cycle cost method, which covers the costs of initial investment, replacement, operation, maintenance and repair, and disposal [15]. The life-cycle cost method sums these costs over a fixed period of time, known as the study period. Alternative products for the same function, say floor covering, can then be compared on the basis of their life-cycle costs. To combine environmental and economic performance into an overall performance measure, BEES uses the ASTM standard for Multiattribute Decision Analysis [14]. The BEES user specifies the relative importance weights used to combine environmental and economic performance scores and may test the sensitivity of the overall scores to different sets of relative importance weights. Supporting data and computations are documented.

BEES Model environmental impact

- Global Warming
- Acid Rain
- Eutrophication
- Fossil Fuel Depletion
- Indoor Air Quality
- Habitat Alteration
- Ozone Depletion
The BEES model uses the ASTM standard classification system, to organize comparable building products into groups. The ASTM standard classifies building components into a three-level hierarchy: major group elements (e.g., substructure, shell, and interiors), group elements (e.g., foundations, roofing, interior finishes), and individual elements (e.g., slab on grade, roof coverings, floor finishes). Elements are defined such that each performs a given function, regardless of design specifications or materials used. The UNIFORMAT II classification system is well suited to the BEES environmental and economic performance methodologies, which define comparable products as those that fulfill the same basic function. The BEES model uses the UNIFORMAT II classification of individual elements, the third level of the hierarchy, as the point of departure for selecting functional applications for BEES product comparisons.

Overall Performance
The BEES overall performance score combines the environmental and economic results into a single score, as illustrated in above Figure to combine them, the two results must first be placed on a common basis. The environmental performance score reflects relative environmental performance, or how much better or worse products perform with respect to one another. The economic performance score, the life cycle cost (LCC), reflects absolute performance, regardless of the set of alternatives under analysis. Before combining the two, the life-cycle cost is converted to the same, relative basis as the environmental score by dividing by the highest-life-cycle cost alternative. Then the environmental and economic performance scores are combined into an overall score by weighting environmental and economic performance by their relative importance values. Overall scores are thereby placed on a scale from 0 to 100; if a product performs worst with respect to all environmental impacts and has the highlife-cycle cost, it would receive the worst possible overall score of 100. The BEES user specifies the relative importance weights used to combine environmental and economic performance scores and may test the sensitivity of the overall scores to different sets of relative importance weight.

IV. OUR APPROACH

Development of Building LCA Model

Assumption
The broader assumptions made are as under:

• The acquisition of building data is mainly focusing on larger building elements, skipping transports etc.
• The inventory analysis is done focusing on the most important substances that contribute to a certain impact category, skip or simplify the end-of-life of the building, only use generic emission data etc.
• Calculations are simplified by focusing on only a few impact categories.
• data acquisition of the building is done by using excel program and thus reduce the time
• The emission factors are used are the data as suggested in the IPUC manual for India condition

Building LCA Model
The LCA model for assessment of institutional building is divided into three major components:
1. Building material
2. Building facility
3. Building surrounding

The first module covers the calculation of material used for the construction, second module covers the calculation of electricity consumption for building facility and the third module covers the calculation of green plantation and surrounding around the building. This generic model can be applied for all types of building. The flow chart developed considering three modules for the estimation of life cycle assessment of building is shown in Figure 2.
Estimation of Environmental Impact Due To Building Materials

The important environmental aspect is about building materials. A great volume of gasses are emitted from the building material. The building material are divided mainly into two categories viz. major building material and minor building material the major building materials are cement, rebar and structural steel, brick, granite, wood, PVC pipes etc. and the minor building materials are polythene, granite, marble, plaster, ceramic, brass, paint etc. while, the some of the materials which are equally as important as the major building material causing environmental impact are categories as other materials. The environmental impact which is causes due to building materials are evaluated in Table 1.

Thus, the summation of environmental impact of above given material gives the total environmental impact. From eq. no 3.1, eq. no 3.2, eq. no 3.3, eq. no 3.4, eq. no 3.5, no 3.6 and no 3.7, Total emission

$$= TE_1 + TE_2 + TE_3 + TE_4 + TE_5 + \cdots + TE_n$$

Total emission  $$= \sum_{i=1}^{n} TE$$

Estimation of Environmental Impact Due To Building Facilities

The operation phase of a building is much longer as compared to the construction. The environmental impacts during the operation phase are mainly from the operation of building facilities, which is electricity-consuming. A great number of pollutants are generated and a large volume of natural resources are consumed in the production of electricity. So the environmental impacts of this phase are indirectly determined by the consumption of energy. In this model the building facilities viz. air conditioning, lifting system, lightning system, equipment and other appliances used. The annual average consumption of electricity can be obtained from design documents. The calculation of environmental impacts from electricity consumption is evaluated in Table 2.
Thus, from eq. no 3.8, eq. no 3.9, eq. no 3.10, eq. no 3.11, eq. no and 3.12,
Total emission (TE) =

\[ = \sum_{i=1}^{n} TE \]

**TABLE 2:**

<table>
<thead>
<tr>
<th>Eq. No</th>
<th>Equation</th>
<th>Description</th>
<th>Total Emission</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.8</td>
<td>Electricity Consumption by Air Condition in KHW X Emission factor = Total emission by air condition</td>
<td>TE1</td>
<td></td>
</tr>
<tr>
<td>3.9</td>
<td>Electricity Consumption by Heating system in KHW X Emission factor = Total emission by heating system</td>
<td>TE2</td>
<td></td>
</tr>
<tr>
<td>3.10</td>
<td>Electricity Consumption by Lightning system in KHW X Emission factor = Total emission by Lightning system</td>
<td>TE3</td>
<td></td>
</tr>
<tr>
<td>3.11</td>
<td>Electricity Consumption by Lifting system in KHW X Emission factor = Total emission by Lifting system</td>
<td>TE4</td>
<td></td>
</tr>
<tr>
<td>3.12</td>
<td>Electricity Consumption by Other Appliances in KHW X Emission factor = Total emission by Other Appliances</td>
<td>TE_n</td>
<td></td>
</tr>
</tbody>
</table>

Thus Total Emission = TE

V. CONCLUSION

The present model developed for life cycle assessment (LCA) and CO₂ emission of building incorporate with building construction material, building energy consumption and building surrounding in life span perspective. The method used in the study was based on Life Cycle Assessment, highlighted the opportunities for reducing the carbon dioxide impacts on the building. The impacts from the operation stage are limited since the decisions taken during the construction stage pre-determine the impacts of the building over its lifetime. Carbon dioxide emissions reduction is an important way for construction projects to realize the targets of low-carbon building. Through analysis, it is found that there are several measures can be taken. Reduce the use of some materials that produce more CO₂ emissions in the producing process. Carbon foot printing can help to identify key construction materials with high-embodied carbon and promote low-carbon alternatives. Comparison of the environmental impact of buildings i.e. carbon emission from buildings is mainly depends upon the location where the building situated, geographical zones, with different uses. It influence all the variables involved in the lifecycle of a building. Evaluation of the influence that the initial decisions adopted in the design phase of a building related to the maintenance.

REFERENCES