COST C12 – WG3

Datasheet III.3.1

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TOWARDS SUSTAINABILITY: LIFE CYCLE ASSESSMENT OF BUILDING PRODUCTS

Introduction

- In building construction, sustainability may be defined as a constant search for planning processes, design, construction, exploration and reconstruction/replacement of buildings, minimizing environmental impact by limiting the consumption of non renewable fossil fuels and non renewable materials, minimizing pollutant emissions, and minimizing waste production.
- Buildings in general last longer in the ecosystem than any other product made by our society. Therefore sustainability might imply the consideration of a minimum lifetime of about 100 years so that renovation/replacement cycles underlying the concept of sustainability can be considered.
- Any assessment of a building's sustainability has to take into account not only the construction phase but also the behaviour of the building over its service life and its final destination/disposal (demolition/recycling) including any change of its functionality that might happen during this period.
- Due to the necessity of assessing the life cycle of a building, particularly the issue of environmental impacts, specific methodologies are being developed - the so-called Life-Cycle Assessment Methods.
- Life-cycle design of building products is a "cradle-to-grave" analysis, from the gathering of raw materials to their ultimate disposal, and each step is examined for its environmental impact.
- A building product's life-cycle can be organized into three phases: pre-building, building and post-building:

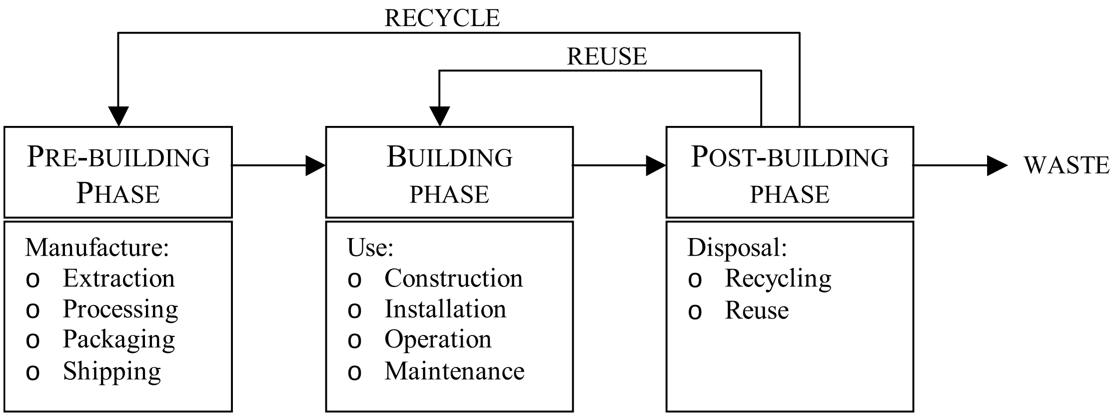

Figure 1. Phases of the building material life cycle

  - The pre-building phase includes the production and the transportation to a construction site, and has probably the most potential for causing environmental damage. A close understanding of the environmental impacts in this phase will lead to a wise selection of building products and materials.

  - The building phase refers to a building material's service life.
  - The post-building phase refers to the building materials at the end of their service life. At this point a material may be completely reused, partially recycled or dispose of.
- In view of a sustainability assessment and as a result of the definition of sustainable development of building construction, several features should be taken into consideration:
  - Social aspects (health, hygiene, security and wellbeing)
  - Economic aspects
  - Functional aspects (flexibility to change the functionality)
  - Technical aspects (durability, reliability and service behaviour)
  - Environmental aspects (consumption of natural resources such as energy, raw materials, water and air; pollution problems and waste production)

Methodology

- A study conducted by the University of Michigan defined criteria that lead to the selection of sustainable building materials. In the table below, those criteria are grouped according to the affected building life-cycle phase. The presence of one or more of these "green-features" in a building material can assist in determining its relative sustainability.

Green Features		
Pre-building Phase	**Building Phase**	**Post-building Phase**
Waste reduction	Energy efficiency	Biodegradable
Pollution prevention	Water treatment & conservation	Recyclable
Recycled	Nontoxic	Reusable
Embodied energy reduction	Renewable energy source	Others
Natural materials	Durability	

  - Waste reduction: measures to reduce waste in the manufacturing process allow to increase the resource efficiency of building materials.
  - Pollution prevention measures taken during the manufacturing process can contribute significantly to environmental sustainability.
  - Recycled content in a product means that it was produced from post-industrial or post-consumer waste. By recycling materials, the contained embodied energy is preserved. The energy used in the recycling process for most materials is far less than the energy used in the original manufacturing.
  - Embodied energy: in most cases the greater a material's embodied energy, the greater the amount of energy required to produce it, implying more severe ecological consequences
  - Natural materials are generally lower in embodied energy and toxicity than man-made materials. They require less processing and are less damaging to the environment.
  - The aim of using energy-efficient materials is to reduce the amount of generated energy that must be brought to a building site. The long-term energy costs of operating a building are heavily dependent on the materials used in its construction.
  - A system for water treatment/conservation allows to increase the quality of water

    and/or reduce the amount of water used on a site.

    - Non-toxic materials are less hazardous to construction workers and building's occupants.
    - Renewable energy systems can be used to supplement or eliminate traditional heating, cooling and electrical systems through the utilization of the natural energy available in nature (wind, solar radiation and geothermal heat)
    - Materials that last longer will, over a building's useful life, be more cost-effective than materials that materials that need to be replaced more often. Durable materials that require less frequent replacement will require fewer raw materials and will produce less landfill waste over the building's lifetime.
    - Very durable materials may have many useful years of service life left when the building in which they are installed reach the end of its service life, and may be easily extracted and reinstalled in a new site.
    - Recyclability measures a material's capacity to be used as a resource in the creation of new products.
    - The biodegradability of a material refers to its potential to naturally decompose when discarded.
- The International Standards Organization has developed a series of standards dealing with environmental management and life cycle assessment in general.
- According to ISO standards series 14040-14049, the general LCA methodology involves four steps: the goal and scope definition, the inventory analysis, impact assessment and interpretation step.
    - The <u>goal and scope definition</u> step spells out the purpose of the study and its breadth and depth;
    - The <u>inventory analysis</u> step identifies and quantifies the environmental inputs and outputs (inventory flows) associated with a product over its entire life cycle.

      In this step the functional unit, which is the subject of the study, is translated into a product system. The scope and boundaries of the system and the involved processes as well as the level of detail have to be defined.
    - The <u>impact assessment</u> step characterizes these inventory flows in relation to a set of environmental impacts. Environmental Impacts are classified in different groups of impacts each with their own characteristics. Normalisation makes it possible to weigh the different impacts and compare them.
    - The <u>interpretation</u> step combines the environmental impacts in accordance with the goals of the LCA study. Results of the LCA calculations need to be analysed and all the choices and assumptions of the analyses need to be evaluated. A number of tests to check the validity of the results are prescribed in the standards.
- Selecting environmentally preferable building products is a fundamental step towards sustainability. However the environmental performance must be balanced against economic performance, so that the methodology can appeal to everyone involved: manufactures, designers and final customers.
- Integrated life cycle design aims to improve on methods to incorporate and balance the most influential aspects: Human conditions, Economic conditions, Culture and Ecologic considerations.

Applications

- The U.S. National Institute of Standards and Technology developed a software program – BEES (Building for Environmental and Economic Sustainability), which implements a methodical technique for selecting environmentally and economically balanced building products. The environmental performance of building products is measured using the environmental life-cycle assessment approach specified in ISO 14040 standards, and the economic performance is measured using the American Society for Testing and Materials standard life-cycle cost method (E917). Environmental and economic performances are combined into an overall performance measure using the ASTM for multiattribute decision analysis E1765.
  - The purpose of this project is to provide a useful tool for the residential sector which will allow a cost-effective reduction in building-related contributions to environmental problems.
  - However, for the time being, this tool has some limitation as the building products are compared as individual components, not taking into consideration the entire building or component assemblies.
- Green-buildings consist of a holistic building strategy making use of environmental planning, design, specification, labour management and technologies to reduce the negative impact development upon the planet. The main guidelines of green-buildings are:
  - Materials efficiency through:
    - Use of existing materials from the site
    - Use of recycled materials
    - Reduction of the quantity of materials and waste.
  - Energy efficiency and greenhouse gas reduction through:
    - Ventilation, heating & cooling
    - Effective management of lighting & equipment energy demands
    - High efficiency artificial lighting
  - Water efficiency and reduced water demand through:
    - Rainwater collection and use
    - Efficient water supply appliances
  - Occupant health, comfort and productivity through:
    - Openable windows
    - Significantly improved internal air quality

Future developments

- Methodologies for integrate life-cycle assessment. Some features such as the technical performance of a building material (durability, long-time behaviour, etc), or building physics should be included in the overall performance.
- New-technology construction materials bring new uncertainties to every project. New models should allow to characterize uncertainty in the underlying data (environmental, technical performance, costs, etc) and to see how these uncertainties affect the overall life-cycle analysis.
- Models integrating sensitivity analysis, in order to analyse how changes in individual parameters can affect the overall analysis.

Examples

- Successful cases study of sustainable building around the world:

  http://www.sustainable.doe.gov/buildings/gbsstoc.shtml

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