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Standard Guide for Environmental Life Cycle Assessment of Building Materials/ Products[1]

This standard is issued under the fixed designation E 1991; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

This is a general guide for the application of environmental Life Cycle Assessment (LCA) as a tool for evaluating the environmental aspects of materials/products, processes, and services produced and used in buildings and the built environment. This guide does not include, necessarily, all of the environmental features and impacts of the complete building life cycle, but focuses on those issues directly related to building materials/products and those elements of the building's environmental performance affected by these materials/products. Fig. 1 illustrates the total life cycle of a building. Fig. 2 is an example of the relationship between the life cycle processes of building materials/products and the total life cycle of a building and illustrates how these product/material life cycle processes merge with the total building life cycle. Fig. 3 illustrates an example of the life cycle of a building construction material within the context of the total building life cycle.

1. Scope

1.1 This guide presents a common framework and set of principles for potential users, such as product manufacturers, environmental analysts, consultants, architects, and the building industry in general. It describes a framework for life cycle inventory analysis, and describes various options and aspects of Impact Assessment and Interpretation.

1.2 The complexity and level of detail of an LCA will vary greatly depending on the material/product or system studied, the purpose and use of the study, the intended users of the study, and the resources committed to complete the study. The level of detail can range from generic to material/product specific.

1.3 This guide does not describe in detail the actual techniques for performing a Life Cycle Assessment.

1.4 Life Cycle Assessment is an emerging methodology, which is still evolving. This guide will present its concepts and major features. It should enable the user to better understand Life Cycle Assessment and its application to building materials/products, and help to identify sources of additional information and guidance. LCA is only one of many tools designed to aid in environmental evaluation and decision making.

1.5 The component phases of Life Cycle Assessment, including goal definition and scoping, inventory, impact assessment, interpretation, and the various methodologies used in these phases are in various stages of development. Consequently, the results of an LCA must be understood in the context of their completeness and accuracy and must be applied appropriately. LCA does not necessarily proceed as a linear process through these phases but is conducted in an iterative fashion.

2. Referenced Documents

2.1 *ASTM Standards:*

E 1765 Practice for Applying the Analytical Hierarchy Process (AHP) to Multiattribute Decision Analysis of Investments Related to Buildings and Building Systems[2]

3. Terminology

3.1 Definitions for most of the LCA terms and language used in this guide can be found in Refs. **(1-7)**.[3] Terms specific to this guide are as follows:

3.1.1 *standard*—a document that has been developed and established within the consensus principles of the Society and that meets the approval requirements of ASTM procedures and regulation.

[1] This specification is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.71 on Sustainability.

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[2] *Annual Book of ASTM Standards*, Vol 04.11.

[3] The boldface numbers in parentheses refer to the list of references at the end of this standard.

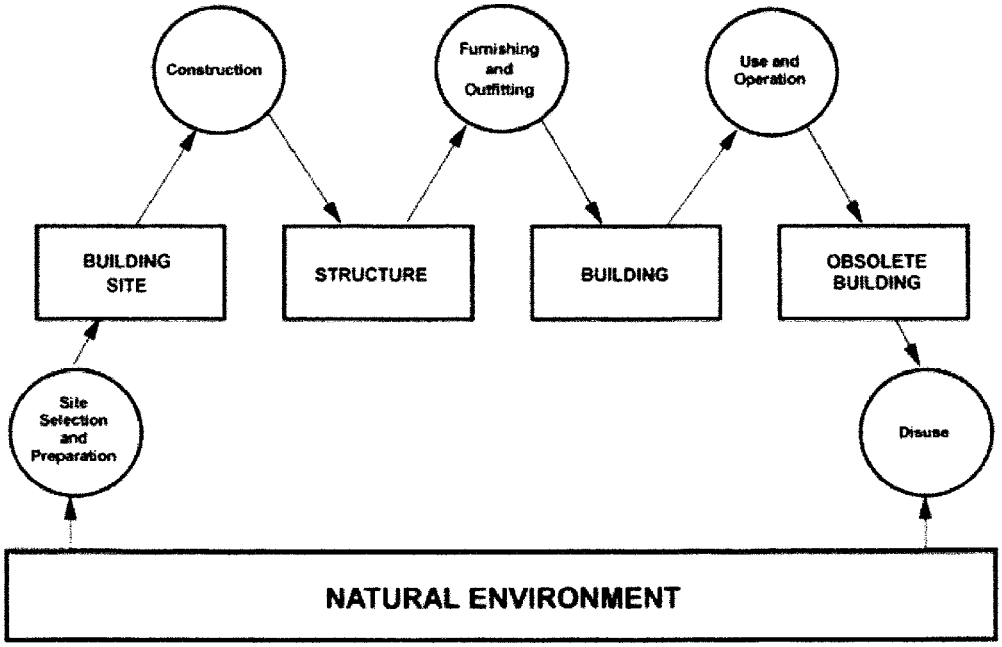

FIG. 1 Total Life Cycle of a Building

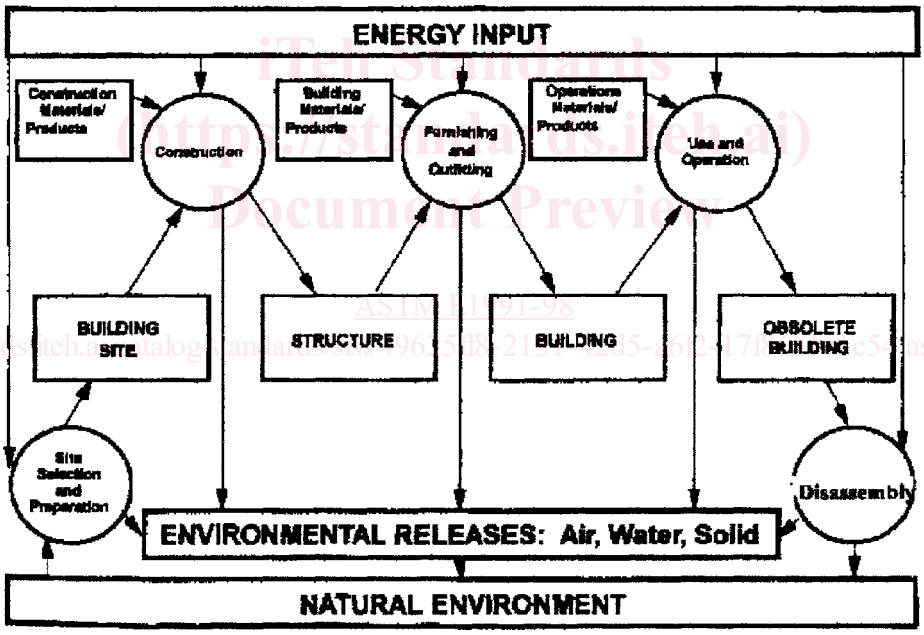

FIG. 2 Flow of Building Materials/Products into Building Life Cycle

3.1.2 *guide*—a compendium of information or series of options that does not recommend a specific course of action.

3.1.3 *practice*—a definitive set of instructions for performing one or more specific operations that does not produce a test result.

3.2 Definitions of terms in Fig. 1, Fig. 2, and Fig. 3:

3.2.1 *building, n*—the complete, outfitted, and furnished structure, operational in every way and ready for occupancy and use.

3.2.2 *building material/product, n*—a manufactured or produced unit or component that goes into any of the building life cycle processes. In the text of this guide, this term is used in a broad context and is meant to include fundamental construction material, for example, stone, as well as manufactured products, such as, windows, roofing, HVAC and electrical systems, interior furnishings, maintenance products, etc., used throughout the total building life cycle.

3.2.3 *construction, n*—the complete series of activities and actions that begins with a building sit and results in a completed structure.

3.2.4 *disassembly, n*—that complete series of activities and actions that eliminates the building.

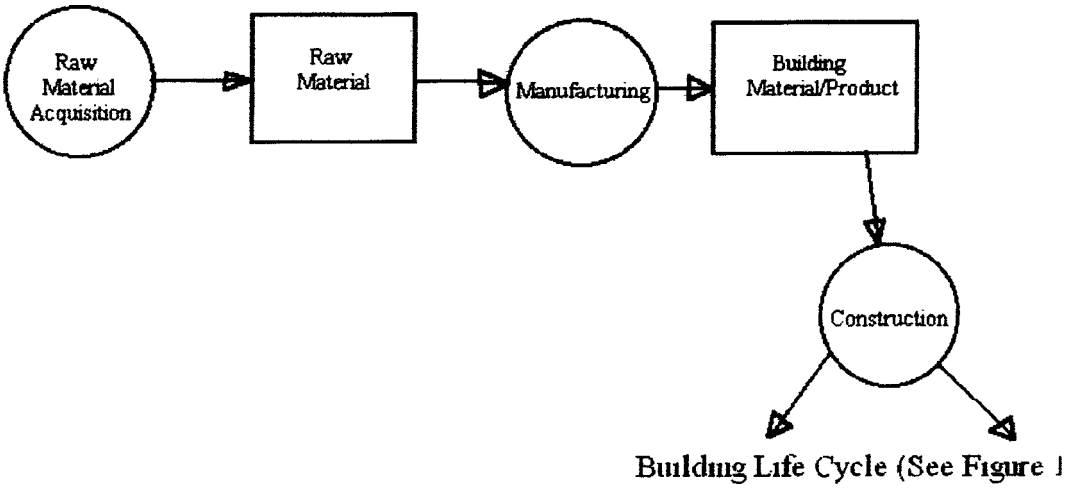

FIG. 3 Example of Building Material/Product Segment of Total Building Life Cycle

3.2.5 *energy input, n*—all forms of energy necessary for the accomplishment of the particular building life cycle process under consideration.

3.2.6 *environmental releases, n*—all air, water, and solid emissions, which are given off by the building life cycle process under consideration that return to the natural environment.

3.2.7 *furnishing and outfitting, n*—the complete series of activities and actions that begins with a building structure and results in a completed building.

3.2.8 *interior furnishings, n*—those temporary and semipermanent systems and components, which generally are required for the normal utilization of the building for its intended purpose including decorative components.

3.2.9 *manufacturing, n*—the complete series of activities and actions that produces the building material/product.

3.2.10 *obsolete building, n*—a building that has reached the end of its useful life.

3.2.11 *raw material, n*—those components and ingredients that enter into the manufacturing process of the particular building material/product under consideration.

3.2.12 *raw material acquisition, n*—the processes by which natural resources are taken from the natural environment, including subsequent processing, to produce raw materials for the manufacture of the particular building material/product under consideration.

3.2.13 *site, n*—the natural location intended for the building altered, modified, and prepared to the point where construction activities can begin.

3.2.14 *sit selection and preparation, n*—the complete process or series of activities and actions that converts, alters, and modifies a natural area or plot of land to a building site ready for construction to begin.

3.2.15 *sponsor, n*—the individual or individuals who have initiated and funded the LCA.

3.2.16 *stakeholder, n*—an individual or collection of individuals who have some substantial interest or concern in the building, its materials/products, or its life cycle processes; or, whose environment is or will be influenced by the building and its life cycle.

3.2.17 *structure, n*—the completed building envelope on the site including all operating systems ready for interior furnishings.

3.2.18 *target audience, n*—the individual or collection of individuals for whom the LCA is being done and to whom the results are being directed.

3.2.19 *use and operation, n*—the complete and ongoing series of activities and actions that occur and are required during the life of a building from the point of occupancy to the point where the building is obsolete and is about to be disassembled.

4. Summary of Guide

4.1 Life Cycle Assessment is a tool for identifying, assessing, and interpreting the environmental aspects, such as, material, natural resource, and energy use; environmental releases and other burdens of a product, process, or activity. A typical LCA can be thought of as consisting of four phases: goal definition and scoping, inventory analysis, impact assessment, and interpretation **(1-7)**.

4.2 Defining a clear and unambiguous goal or purpose of the LCA is essential at the outset. Doing so will assist in imposing boundaries on the study and will help to establish the scope of the effort. Identification of the target audience also is important to establishing the scope. Depending on the goal and purpose of the LCA, other parts of the process may involve identifying the relevant stakeholders throughout the life cycle, ranking the degree to which the various stakeholders interests will be accommodated in decision making processes, and identifying stakeholder priorities regarding the various potential impacts possible throughout the life cycle.

4.3 The inventory analysis will comprise a process analysis of the Life Cycle of the subject of the LCA, in this case the building material/product. Fig. 1 illustrates the life cycle of a building. Fig. 2 illustrates how the life cycle of a building material/product merges with the life cycle of the building. This analysis of the life cycle process then is followed by a compilation of the relevant inputs and outputs of the processes

making up the total system. The depth of this analysis will be consistent with the goal, scope, and intended use of the study **(1, 2, 3, 5, 6, 7)**.

4.4 Impact assessment will consist of an evaluation of the potential environmental impacts of the inputs and outputs of the total system. The general categories of environmental impacts to be considered may include resource use, human health, and ecological consequences. **(1, 4)**.

4.5 Interpretation of the results of the inventory analysis and the impact assessment must be made in relation to the goal and intended use of the LCA.

4.6 The application of the Life Cycle Assessment concept to decision making processes for the reduction of the environmental consequences of a building, and its materials/products is an iterative process and generally will involve the examination of a variety of options. Because this takes into consideration impacts on all environmental media and examines the entire material/product life cycle, LCA provides the user with an opportunity to achieve actual reduction in environmental impact and not a shift of impact from one medium to another, from one geographical area to another, or from one part of the life cycle to another.

4.7 This guide provides general guidance for initiating the performance of a LCA for buildings and building materials/products and illustrates some of the potential benefits derived from its use.

5. Significance and Use

5.1 Life Cycle Assessment in its broadest context is a holistic, comprehensive concept with many potential applications. Currently, there are numerous organizations, from both the public and private sectors, such as the Society of Environmental Toxicologists and Chemists (SETAC), ISO, many national standards organizations, universities, private companies, consulting groups, etc., working in the area of environmental life cycle assessment. Each group has its own specific set of objectives and requirements. This guide includes the elements of Life Cycle Assessment on which general consensus has been reached and incorporates them into a guide tailored to buildings and building materials/products.

5.2 This guide provides general guidance for the practice of conducting LCA on building materials/products for the purpose of making decisions and choices.

5.2.1 Those who specify or select materials for use in buildings will benefit from the guidance provided here in that it will provide a means of incorporating environmental considerations into their decision-making processes.

5.2.2 Those who develop, manufacture, and market building materials/products will benefit from the guidance provided here in that it will enable them to more objectively assess the environmental implications of new products, designs, and processes; evaluate existing products, designs, and processes; and compare other product and process alternatives.

5.2.3 This guide offers guidance that can be helpful in minimizing the subjectivity often associated with environmental decision making and will foster more consistent, more complete assessments and decisions regarding the environmental aspects of building materials/products. Even with this guidance, results may vary greatly.

5.2.4 See Appendix X1 for some specific examples of the potential applications or uses of Life Cycle Assessment as suggested in this guide. Application and use can have either an internal or external focus. An internal application is intended primarily for the use of the sponsor and focuses on some internal aspect, material, or process over which the sponsor has primary control and influence. In this case, the sponsor is the exclusive audience. An external application is intended either primarily or secondarily for use by some stakeholder external to the sponsor. In this case, the sponsor and one or more external stakeholders are the audience for the LCA. A critical review by knowledgeable expects should be done for all external applications of an LCA.

5.2.5 In the application of LCA to building materials/products, the environmental information developed by the LCA often will be only part of a series of issues and factors to be considered in a more complex decision making process. In the building industry decisions generally will depend on more than an assessment of environmental impact. Other factors and considerations, such as economics, material/product performance and function, aesthetics, availability, timing, etc., almost always will intervene. The decision making process must accommodate these factors. Procedures exist, which will be useful in this process (see Practice E 1765 and Ref **8**).

5.2.6 It should be recognized that in conducting an LCA on building materials/products there are certain considerations that differentiate it from an LCA on nondurable consumer products, such as:

5.2.6.1 Durability of alternative materials/products for a given application may vary significantly.

5.2.6.2 Building use patterns can change during the life of the materials/products.

5.2.6.3 Environmental effects during the use stage can dominate the total environmental impact.

5.2.6.4 Building site and location can affect the environmental profile.

5.2.6.5 Materials/products often are incorporated into assemblies with other materials/products and must be considered in the context of those assemblies and their environmental implications.

5.2.6.6 Environmental impacts may depend on how materials/products are used and maintained.

6. Procedure

6.1 The following section describes in more detail the content and components of an LCA as it relates to building materials/products. The information contained herein is not intended to be exhaustive. Rather, it is intended to provide an overview and assist the user in deciding how to undertake an LCA and how the results might be applied.

6.1.1 There are four major phases in conducting an LCA. They are goal definition and scoping, inventory analysis, impact assessment, and interpretation. In the context of this guide, the application of a complete LCA will involve the application of these four phases to a series of building and building material/product options and choices for the purpose of decision making (see Fig. 4).

6.1.2 The four phases will be discussed here as a methodology for the evaluation of a single material, product, or