



# Standard Guide for Environmental Life Cycle Assessment of Building Materials/ Products<sup>1</sup>

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 ( $\epsilon$ ) 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<sup>2</sup>

### 3. Terminology

3.1 Definitions for most of the LCA terms and language used in this guide can be found in Refs. (1-7).<sup>3</sup> 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.

<sup>1</sup> 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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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 04.11.

<sup>3</sup> The boldface numbers in parentheses refer to the list of references at the end of this standard.

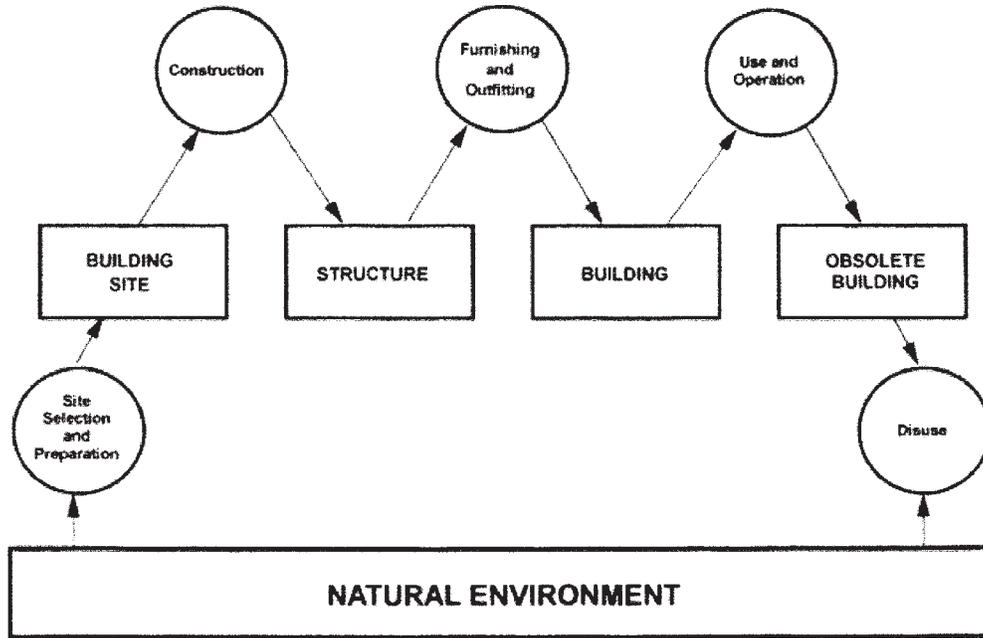


FIG. 1 Total Life Cycle of a Building

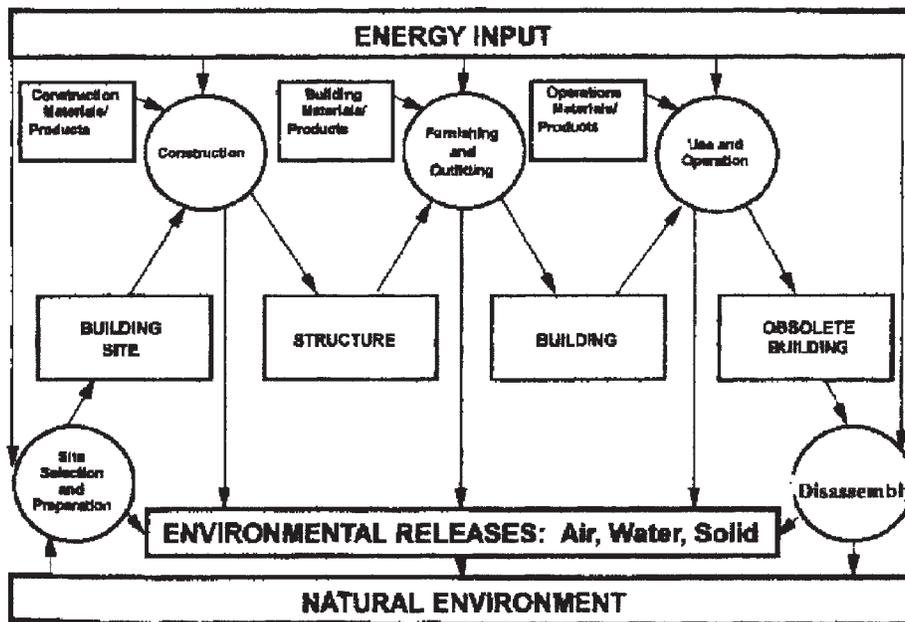


FIG. 2 Flow of Building Materials/Products into Building Life Cycle

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:

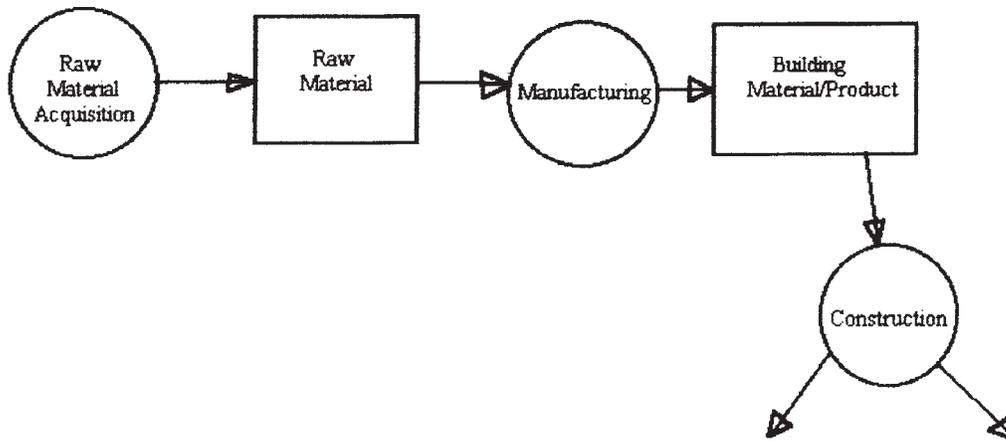
3.2.1 *building, n*—the complete, outfitted, and furnished structure, operational in every way and ready for occupancy and use.

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.



Building Life Cycle (See Figure 1)

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 *site 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 experts 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

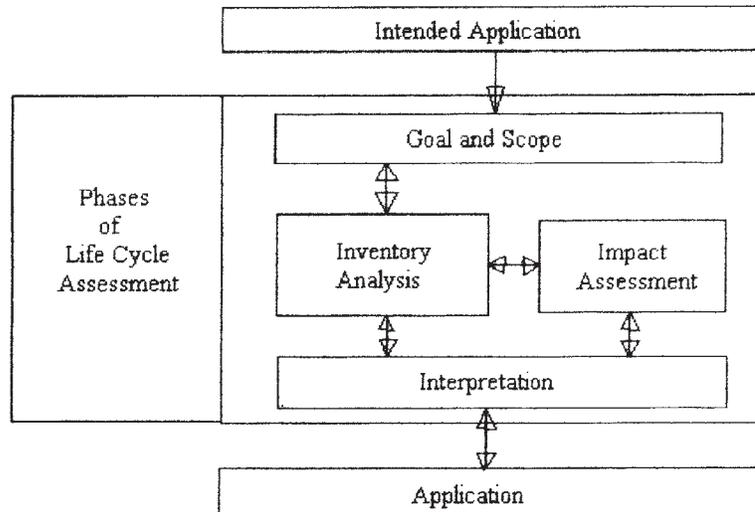


FIG. 4 Outline of LCA for Building Materials/Products

activity. When evaluating alternate materials/products, alternate process options, or when making comparative assertions, it is essential that the LCAs of each of the options be conducted in a thorough, consistent, and comparable manner so that comparisons are valid.

6.2 *Goal Definition and Scoping:*

6.2.1 The purpose, goal, or intended use of the LCA must be defined clearly and unambiguously prior to proceeding. This provides the project/problem definition, enables the setting of boundary conditions for the analysis, and establishes the objectives of the study.

6.2.2 The purpose, goal, and intended use also will determine the level of detail and the depth of the Life Cycle process analysis required.

6.2.3 Data quality targets also will be set. It must be realized that achieving these data quality targets may not always be possible. The available data and the quality of those data will depend upon many things, such as source, completeness, precision, etc. As data are collected throughout the study, it is important to record a measure of data quality.

6.2.4 The target audience of the study should be identified. The target audience is the principal audience for whom the results of the study are intended. The target audience may be internal to the entity sponsoring the study, or the study may be intended for use by the sponsor with some audience external to the sponsor. Often, it is the case that there are several target audiences to be considered. This is particularly the case for a building since it has an extended lifetime and since it interfaces with many stakeholders.

6.2.5 It is important in setting the goal and scope to identify not only the target audience but also all of the relevant stakeholders who will have some stake in the total environmental impact of the building and its materials/products. The stakeholders can be of several different types. For example, the sponsor of the LCA is a stakeholder and certainly a target audience. Those affected by the environmental impacts throughout the life cycle also are stakeholders, and depending on the purpose of the LCA, some also may be part of the target audience. Also, it may be important for the decision maker

(user of the LCA) to establish the degree to which stakeholder’s values and views have been considered and accommodated in the decision making process.

6.2.6 At the goal definition and scoping stage, the LCA is specifically designed and planned with the intended use, audience, and stakeholders in mind. Consequently, a study designed to provide product or process improvement may be unsuitable for use in marketing or educating the public.

6.3 *Defining the Scope:*

6.3.1 In defining the scope of a study, the following issues should be considered and clearly described: the function of the material/product system under consideration; the functional unit; the system boundaries; temporal features and time scales; geographic and locational aspects; the extent, type, and methodology of impact assessment processes to be used; data and data quality requirements; known assumptions and limitations; and, methods to be used to evaluate the significance of differences revealed in the inventory and impact assessment.

6.3.2 The “functional unit” is a descriptor or measure of the service or function performed by the material/product system under consideration. The purpose of defining the functional unit for an LCA study is to permit comparison of equivalent items or services (functions). The functional unit is to provide a means of comparing different materials/products or designs for a given function. For items to be functionally equivalent, they must be able to meet a defined need (function) within specified use, performance, and time parameters.

6.3.2.1 The functional unit for an interior wall paint or finish may be defined as effective coverage of and performance on a given area of interior wall surface for a specified time period. Then, depending on the properties and performance of the paint or finish options, this unit will be defined further in terms of a specific number of gallons or some other quantity in units more common to the material under consideration. In general, a comparison on a gallon for gallon basis may not necessarily be valid. For example, one paint may require different numbers of applications than the alternative to achieve the desired performance.

6.3.2.2 The functional unit for a floor covering could be defined as a specific area of coverage of the subfloor meeting specified use and performance characteristics, installation requirements, aesthetic qualities, and maintenance properties, for a given period of time. Durability and lifetime of the material, recyclability, impact on indoor air quality, cost, etc., are important factors to be considered.

6.3.2.3 Definition of the functional unit can sometimes be complex in the case of building materials, particularly when several different options of very different design are under consideration; however, it is necessary to define clearly some equivalency in order to fairly compare the options. The functional unit for building materials may involve several specific functions simultaneously and will include an accounting for the expected life of the material. The functional unit must be quantifiable, measurable, and definable in terms of some unit characteristic of the material or design. Accurately and completely defining the functional unit is very important in ensuring equivalency in comparing options, alternatives, and in making comparative assertions.

6.3.3 The system boundaries are determined by the goals and objectives of the LCA. These boundaries are defined more specifically by which operations, processes, and subsystems are included and by which inputs and outputs are included in the study. When availability of data affects the system boundaries it should be so recorded.

6.3.4 The life cycle of a building material/product involves considerations of durability and expected life span. The scope should define clearly the anticipated life of the material and time frame over which the system is being studied. Likewise, environmental impacts can be time dependent and the system should account for such temporal features.

6.3.5 The scope of the study should take into account geographical and locational considerations that can have an effect on the impacts of the system. Environmental impacts can be very dependent upon location and geography. Some impacts can be of global scale and some only of local scale.

#### 6.4 *Data Quality:*

6.4.1 Data quality assessment is a systematic approach to measuring the suitability of the data for its intended purpose. The quality of the data used in an LCA in large measure determines the degree of confidence the user will have in the ultimate results of the LCA and the decisions that result. Data quality is a representation of the reliability of the individual data and in the data set as a whole.

6.4.2 Data quality goals are specifications of the required quality of the data based on a set of data quality indicators. The goals and objectives of the LCA can assist in establishing minimum data quality goals. The data quality achieved may to some degree be dependent on the level of effort allocated to the study which will be a function of the purpose, budgetary and time constraints, and data availability. Inability to meet the data quality goals may require modification of the goals and scope of the LCA.

6.4.3 Data quality indicators are quantitative or qualitative measures of the credibility of the data. Data quality indicators should address such things as precision, accuracy, reproducibility, variability, completeness, consistency, source, uncertainty, etc.

6.4.4 Data quality assessments are an important element in drawing conclusions and making decisions. As a result, every effort should be made to determine and record the quality of all data, the uncertainty associated with it, and the significance of these uncertainties.

#### 6.5 *Life Cycle Inventory Analysis:*

6.5.1 Life cycle inventory analysis involves the identification and quantification wherever possible of all inputs and outputs of the system under study including natural resources; energy; releases to air, water, and land; coproducts; and, open- and closed-loop recycling. The process of conducting the inventory is iterative. As the inventory proceeds various aspects of the scope and goal may be affected. New data requirements or limitations may be identified that require changes to the original plan. Any such modifications to the scope and goal must be recorded.

6.5.2 The inventory investigation for a building material/product generally will require information on the four main stages of the life cycle: raw material acquisition, manufacturing, use, and disposal. Aspects of the life cycle, such as maintenance, repair, reuse, and recycling are included in appropriate stages.

6.5.2.1 Raw material acquisition includes all activities and processes required to obtain all the raw materials, energies, and other material requirements for the material/product system. This includes acquisition of natural resources, such as mining or petroleum drilling, as well as subsequent refining and processing of these materials, including distillation, polymerization, firing, etc. Transportation activities associated with this part of the life cycle also are included.

6.5.2.2 Manufacturing activities can include natural resource conversions not accounted for in the raw material acquisition stage, other material or intermediate manufacture, product fabrication or assembly, packaging, and distribution.

6.5.2.3 Use activities comprise those processes involving the consumption, installation, utilization, maintenance, repair, etc., of the material/product to the point where it has completed its intended function. Because of the longevity of buildings and building materials/products, a thorough analysis of this phase is particularly important. For building materials/products, because of their extended lifetimes, the use phase often will dominate the environmental impacts of the life cycle.

6.5.2.4 End of useful life processes and activities include the return or release to the environment of the material/product system but also may include reuse, recycling, or other waste management options.

6.5.3 The primary activities involved in the inventory process are life cycle material and process flow analysis and

identification of inputs and outputs at each step of these processes. This involves data collection, data compilation, and data presentation.

**6.5.3.1 Data Collection**—All material inputs and outputs for each of the process and subprocess steps within the boundaries of the system are identified, quantified, and compiled to the extent possible or to the extent required by the goal and scope of the study. This compilation will include raw materials, other materials and products relevant to the system, energy usage, and environmental releases. Data collection may require substantial commitments in funds and staff time. Practical constraints should be taken into consideration and documented in the scope of the study.

**6.5.3.2 Data Compilation**—The data is assembled into a format that will allow for further manipulation and analysis. All data will be compiled as some quantity per the defined functional unit. Data aggregation procedures can be used if they are useful and consistent with the scope and goal. Such aggregation procedures should be stated, documented, and justified clearly. Nonaggregated data also should be available. Because of complexities and multiple outputs of the processes in the life cycle, it will become necessary to allocate certain inputs or other inventory items to these multiple outputs. For example, a process that uses energy to produce several useful outputs only one of which is associated directly with the subject of the LCA will require that this energy be allocated properly to the various output products. The basis for this allocation will be dependent on the goal and purpose of the LCA. Such allocation procedures must be stated, documented, and justified clearly. The sources and quality of all of the data also should be recorded and explained.

**6.5.3.3 Data Presentation**—The data presentation and format will be consistent with the goals and objectives of the LCA. In the case where impact assessment is to be conducted, the data will be presented in a form anticipated by the impact assessment procedures. Presentation of data and data quality should be sufficient to enable the users to understand and evaluate the study results. Data presentation should be clear, complete, and documented, including sources of data and assumptions underlying the study. Data and results shall be presented in a way that allows the user to determine whether differences between alternative materials/products are statistically significant. If information on the statistical significance of differences is not available, the presentation of the data and the results shall be accompanied by a statement indicating that it is not possible to determine the statistical significance of differences, and an outline of the nonstatistical basis for characterizing the significance of any differences.

## 6.6 Impact Assessment:

**6.6.1** Impact assessment is aimed at characterizing and assessing the impacts of the environmental loadings identified in the inventory analysis. The level of detail and methodologies of impact assessment will depend on the goal and scope of the study. The process of impact assessment is not completely developed. There is no generally accepted methodology for consistently, comprehensively, and accurately associating in-

ventory data with potential environmental impacts. As a result, it is important that assumptions and methodology are described and reported clearly.

**6.6.2** Impact assessment comprises three components: classification, characterization, and valuation.

**6.6.2.1** Classification involves the assignment of inventory data to one or more appropriate impact categories. Impact categories can include changes to air, water, and soil quality or availability, as well as effects on ecological systems, human health, and natural resource stocks.

**6.6.2.2** Characterization describes and estimates the contribution of the inventory items to the related impacts.

**6.6.2.3** Valuation occurs when the different impact categories are evaluated and assigned weights so that they can be compared among themselves. The weighting may involve objective and subjective assignments of relative values and will be affected not only by the severity of environmental degradation but also by the values and opinions held by the stakeholders of concern. The purpose of this step is to establish a further interpretation and aggregation of the data of the impact assessment to enable the relative importance of the impact categories to be assessed.

**6.6.2.4** Important factors that intervene in impact assessment are geographical and temporal factors. The geographical location of an environmental burden needs to be considered in impact assessment. Likewise, the environment is a dynamic system and the effects of time are an important consideration.

## 6.7 Interpretation:

**6.7.1** Interpretation is the phase of the LCA in which the findings of the inventory and the impact assessment are examined and conclusions are drawn with reference to the goals and objectives of the LCA. As indicated in Fig. 4, interpretation may be based on the inventory analysis alone or on the results of an impact assessment or on some combination of inventory data and impact assessment results. The goal and scope of the study will determine what form the interpretation takes and how detailed its output. Interpretation may involve reconsideration and revisions of the scope and data considerations. The finding of this phase should reflect the results of any sensitivity or uncertainty analysis that may have been performed. It is important that all assumptions in connection with this phase be explained and recorded.

**6.7.2** Interpretation generally will be a preliminary step to the application of the LCA in a decision making process in connection with building materials/products. Interpretation usually will involve only environmental issues and concerns and will constitute the environmental effects portion of the input to a final decision making process. Other considerations, such as performance, functional benefits, cost, etc., become part of the application process.

**6.7.3** When comparing differences between alternative materials/products, the user is urged to have the data prepared so that statistical analysis can be used to measure significance of differences. Lacking a sound statistical basis for comparison, users should be cautious in concluding differences between alternative materials/products exist and should understand the basis for concluding those differences.

6.7.4 The interpretation phase of LCA is still undergoing development.

## 7. Critical Review

7.1 The user of the LCA may elect to conduct a critical review of the study. Some purposes of a critical review may be to assure that the study met the established goals; to enhance the credibility of the LCA; or, to provide an external evaluation regarding the quality of the study.

7.2 A review may be carried out internally or externally by recognized experts. If public credibility is important, the independence of an external expert will be beneficial. These experts shall have recognized, relevant scientific and technical expertise and shall be familiar with the requirements of this guide. Critical review by experts should be done for all LCAs that will be used externally. External review does not necessarily guarantee a higher quality review.

7.3 A critical review can evaluate the methods used, the data collected, the interpretations drawn, and the limitations under which the study is conducted. It does not validate the goals, objectives, uses, or conclusions of the LCA.

## 8. Reporting

8.1 Reporting can and should be tailored to the target audience or intended user of the study. The target audience usually will have an effect on the level of detail of the report. The various types of reporting categories may include a full report, a scientific release, an executive summary, an educational release, and a press release.

8.2 Regardless of the category of report provided, each report must make clear the study goals and objectives, scope, assumptions, data sources, sensitivity of the results to changes in key assumptions, statistical (or other) basis for concluding that differences between alternatives materials/products are significant, and conclusions. A good report will allow the

reader, regardless of their perspective, to evaluate the study and use the data to draw their own conclusions. A full report always should be made available, especially when the LCA is reported externally.

8.3 Reporting should be objective and unbiased, fair and accurate. In particular there should be a clear indication of what has and what has not been included in the study, what methodologies have been used, assumptions, data gaps, data quality, etc. A description of these characteristics often is referred to as the transparency of the LCA. Where appropriate, the needs of different users should be recognized and addressed when presenting or disseminating the study. The suggested content of a full report is shown in the following outline:

- 8.3.1 *Goals and Objectives,*
- 8.3.2 *Scope,*
- 8.3.3 *Summary,*
- 8.3.4 *System Boundaries,*
- 8.3.5 *Functional Unit,*
- 8.3.6 *Product/System Life Cycle Description,* (including flow diagrams),
- 8.3.7 *Methodology,*
- 8.3.8 *Data and Data Quality Indicators,*
- 8.3.9 *Data Presentation,*
- 8.3.10 *Inventory Analysis,*
- 8.3.11 *Impact Assessment,*
- 8.3.12 *Interpretations and Conclusions,*
- 8.3.13 *Critical Review,* and
- 8.3.14 *Identity and Qualifications of the Company or Lead LCA Reviewer.*

## 9. Keywords

9.1 buildings; building materials; building products; decision making; environment; environmental effects; impact assessment; input/output analysis; inventory analysis; life cycle assessment (LCA)

## APPENDIX

### (Nonmandatory Information)

#### X1. Potential Internal and External Applications for Life Cycle Assessment

NOTE X1.1—This list is not intended to be an exhaustive one. It is intended to suggest potential applications.

##### X1.1 *Internal Applications:*

- X1.1.1 Compare alternate raw materials.
- X1.1.2 Evaluate manufacturing process changes or new processes.
- X1.1.3 Evaluate alternate product designs and forecast potential impact.
- X1.1.4 Assess environmental effects associated with a business, that is existing, new, or for acquisition.
- X1.1.5 Identify the materials, processes, or systems of an operation that generate significant environmental impact, or a combination thereof.

- X1.1.6 Training and education of internal associates.
- X1.1.7 Evaluate sites for operating or locating a facility.

##### X1.2 *External Applications:*

- X1.2.1 Evaluate environmental impact for reduction of future regulatory liability.
- X1.2.2 Help develop long-term corporate policy regarding overall material use, resource conservation, and reduction of environmental impacts and risks.
- X1.2.3 Aid in training and educating designers, architects, builders, building owner and operators, etc., in the proper use of environmental assessment for the selection of lower impact materials/products, designs, and building processes and operations.

X1.2.4 Provide information that allows customers, consumers, and other stakeholders to evaluate and differentiate between different materials/products and design alternatives.

X1.2.5 Provide information to policy makers and the public about the environmental impacts associated with materials/products and design alternatives.

X1.2.6 Help develop policy on overall material use, waste management and resource conservation, and reduction of environmental impacts.

## REFERENCES

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