



Standard Practice for Evaluating and Reporting Environmental Performance of Biobased Products¹

This standard is issued under the fixed designation D 7075; 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

Biobased materials and products offer potential environmental benefits, energy savings, and reduced consumption of nonrenewable resources. However, there is a need for standard approaches and procedures for comparing the overall environmental benefits and burdens of biobased products and non-biobased products that are used in similar applications. Such comparisons are needed, among other uses, by industry and governmental institutions in selecting materials and products in making purchasing decisions.

An approach for determining the biobased content, resource consumption and environmental profile of biobased products has recently been published as an ASTM guide (D 6852), which provides a framework for assessing the environmental profile of a biobased product.

Guide D 6852 proposed the use of life cycle assessment (LCA) as the tool for assessing the environmental performance of biobased products and deferred to future ASTM standards for additional details.

The subject of this practice is to provide additional guidance for evaluating the environmental profile or performance of biobased products. For consistency in decision-making, the LCA approach shall be further defined for biobased products, although the overall approach is applicable for non-biobased products as well.

This practice is in accord with concepts and terminology used in ISO Standards on LCA (ISO 14040–14043) and is designed as a guide through the steps of LCA assessment. References are provided to the more detailed ISO Standards pertinent to each step.

This practice is aimed at technical professionals not directly involved in LCA evaluations who desire to become familiar with the methodology of LCA as it relates to biobased products.

1. Scope

1.1 Environmental performance shall be measured using the life-cycle assessment (LCA) approach. LCA is a “cradle-to-grave” approach that evaluates all stages in the life of a product, including raw material acquisition, product manufacture, transportation, use and ultimately, recycling (that is, “cradle to cradle” and waste management).

1.2 LCAs for biobased products shall be conducted and communicated in a similar manner, including consistent boundary conditions, functional units, environmental indicators, and reporting formats.

1.3 This practice is limited to environmental performance metrics and excludes other metrics such as those related to economics and social equity.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*²

D 6852 Guide for Determination of Biobased Content, Resources Consumption, and Environmental Profile of Materials and Products

D 6866 Test Methods to Determine the Biobased Content of Materials Using Radiocarbon and Isotope Ratio Mass Spectrometry

¹ This practice is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.96 on Environmentally Degradable Plastics and Biobased Products.

Current edition approved December 1, 2004. Published December 2004.

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

D 7026 Guide for Sampling and Reporting Results for Determination of Biobased Content of Materials via Carbon Isotope Analysis

2.2 ISO Standards:

ISO 14040 Environmental Management—Life Cycle Assessment—Principles and Framework³

ISO 14041 Environmental Management—Life Cycle Assessment—Goal and Scope Definition³

ISO 14042 Environmental Management—Life Cycle Assessment—Life Cycle Impact Assessment³

ISO 14043 Environmental Management—Life Cycle Assessment—Life Cycle Interpretation³

ISO 14049 Environmental Management—Life Cycle Assessment—Examples of Application of ISO 14041 to Goal and Scope Definition and Inventory Analysis³

2.3 U.S. Federal Government Document:

Public Law 107-171 Farm Security and Rural Investment Act, May 13, 2002⁴

3. Terminology

3.1 Definitions:

3.1.1 *biobased material(s)*, *n*—materials containing carbon based compound(s) in which the carbon comes from contemporary (non-fossil) biological sources.

3.1.1.1 *Discussion*—Carbon in contemporary (new, of that period) biological sources comes from recently fixed carbon dioxide (CO₂) present in the atmosphere using sunlight and energy (that is, via photosynthesis in plants).

3.1.1.2 *Discussion*—Solar radiation causes some carbon in the atmospheric CO₂ gas to become a radioactive isotope C-14. Once captured, the CO₂ decays to the stable isotope N-14. This process is slow on a human time scale; the C-14 content decreases by factor of two roughly every 5000 years. However, when it reaches fossil age, which is measured in millions of years, there is no more C-14 radioactive isotope left in the carbon. Thus, biobased carbon (contemporary carbon) has C-14 radioactivity associated with it that can be measured, while fossil carbon (non-biobased) has no radioactivity associated with it.

3.1.2 *biobased product*, *n*—product generated by blending or assembling biobased materials, either exclusively or in combination with non-biobased materials, in which the biobased material is present as a quantifiable portion of the total product mass of the product.

3.1.3 *elementary flow*, *n*—material or energy entering the system being studied, which has been drawn from the environment without previous human transformation, (per ISO 14040) and material or energy leaving the system being studied, which is discarded into the environment without subsequent human transformation (per ISO 14040).

3.1.4 *functional unit*, *n*—quantified performance of a product system for use as a reference unit in a life cycle assessment study (per ISO 14040).

3.1.5 *impact category*, *n*—class representing environmental issues of concern to which LCI results may be assigned.

3.1.6 *impact category indicator*, *n*—quantifiable representation of impact category, that is, CO₂ and CH₄ are quantifiable indicators of global warming impact category.

3.1.7 *life-cycle assessment*, *n*—collection and assembly of materials and energy input and output data including an evaluation of the potential environmental impacts of a specified product system.

3.1.8 *life-cycle impact assessment*, *n*—assessment of a product system's environmental performance through identification and evaluation of relevant impact categories.

3.1.9 *life-cycle inventory*, *n*—collection and assembly of materials and energy input and output data for a specified product system. LCI is only one of the phases in conducting an LCA and is not an assessment of the environmental impacts associated with the product system.

3.1.10 *organic material*, *n*—material containing carbon-based compound in which the element carbon is attached to other carbon atoms, hydrogen, oxygen, or other elements in a chain, ring, or three-dimensional structure.

3.1.11 *reference flow*, *n*—measure of the needed outputs from processes in a given product system required to fulfill the function expressed by the functional unit (per ISO 14041).

4. Summary of Practice

4.1 This practice outlines the recommended procedures for evaluating the environmental performance study and reporting environmental performance results for biobased products as well as fossil resource based products. An LCA approach shall be used which is based on the ISO 14040 series of LCA standards.

4.2 The general LCA methodology involves several distinct stages. The goal and scope definition steps spell out the purpose of the study and its breadth and depth. The inventory analysis step identifies and quantifies the environmental inputs and outputs associated with a product over its entire life cycle. Environmental inputs include water, energy, raw material, land and other resources. Outputs include releases to air, land, and water. However, it is not these inputs and outputs, or inventory flows that are of primary interest. Rather, it is their potential consequences, or impacts, on the environment that are of most concern. The next LCA step, impact assessment, characterizes these inventory flows in relation to a set of environmental impacts. For example, the impact assessment step relates carbon dioxide emissions, a flow, to global warming, an impact. Finally, the interpretation step combines the environmental impacts and describes the results in a manner and language in accordance with the goals of the LCA study.

4.3 LCA methods, some computerized, based on or in accord with ISO 14040 series, are available for evaluation of LCA. One well-recognized methodology, used as a starting point for several other methodologies is the Dutch CML (Center voor Milieukunde, Leiden, Holland).⁵ In the United States, the EPA Office of Research and Development has

³ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

⁴ Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401.

⁵ CML: Product Innovation and Eco-Efficiency, Klostermann, J. E. M., Tukker, A., (eds), Centre for Environmental Science, University of Leiden, 1998.

compiled another widely known system named TRACI or Tools for Reduction of Chemical and Other Impacts.^{6,7} A further comprehensive source that will be available in the future is SETAC/UNEP (United Nations Environmental Programme/Society of Environmental Toxicology and Chemistry) Life Cycle Initiative.⁸ Each of these offers a set of impact categories into which individual pollutants and other environmental factors such as land use will be gathered.

4.4 There is considerable overlap between the various lists of impact categories that have been proposed and are used.

4.5 In this practice, the U.S. EPA TRACI methodology and list of impact categories and conversion factors for category indicators will be used. However, there is no universally applicable, comprehensive list of impact categories suitable for all applications and all materials. Such lists furnish only a point of departure to be augmented or reduced based on the particular situation.

4.6 LCA assessment involves values judgment and use of conversion factors that are subject to debate. Any method used to develop a LCA analysis for biobased products must be transparent and provide access to all data at all stages. All assumptions and value choices made must be clear and readily accessible to the user. The results for each selected environmental impact category must be reported.

5. Overview of Steps in Development of LCA

5.1 A schematic of the sequence of steps involved in development of a LCA is shown in Fig. 1. A life cycle assessment (LCA) consists of four independent elements (see Fig. 1), which have been standardized internationally (ISO 14040 series Standards, 1997-1999). These are:

- 5.1.1 Definition of goal and scope,
- 5.1.2 Life cycle inventory analysis (LCI),
- 5.1.3 Life cycle impact assessment (LCIA), and
- 5.1.4 Life cycle interpretation.

6. Life Cycle Goal and Scope Definition

6.1 *Describe the Scenario*—A brief description of the product and origin of environmental concerns will help the reader appreciate the significance of the subsequent steps. The basic assumptions should also be stated at this point.

6.2 *Define Goal of LCA:*

6.2.1 The goal defines the purpose of the LCA study in its broadest terms, with emphasis on the intended application of results of the study and the audience to whom the results will be conveyed.

6.2.2 A clear, unambiguous goal statement is key to proper formulation of subsequent steps.

6.3 *Define Scope of the Study:*

6.3.1 The scope defines the specific boundaries of the LCA in a way that the goal will be fulfilled. Such considerations would include:

6.3.1.1 Boundaries: cradle-to-gate versus cradle-to-grave study,

6.3.1.2 Process boundaries, which include all environmentally relevant steps, so that process flows in and out of the system, will be elementary flows,

6.3.1.3 The environmental impact categories to be considered must also be stated in the scope (see Section 8). This list must be comprehensive for the product system under evaluation and include any category indicators of concern,

6.3.1.4 This list maybe revised upon examination of material and energy flows (see Section 7),

6.3.1.5 Quality of data requirements (completeness of mass balances, precision, and so forth),

6.3.1.6 Allocation methods for shared operations,

6.3.1.7 Time element to be considered (inputs/outputs to be averaged over a period of time, for example, a year), and

6.3.1.8 Type and format of reporting of the study results.

6.3.2 The scope phase helps to assure that the goal is achieved and the work is done without excessive effort.

6.4 *Define Functional Unit*—Functional unit defines the amount of material or product needed to fulfill the stated task or service. It will form the basis of normalizing the inputs and outputs in the subsequent steps and allow comparison between products in a rational manner. Proper choice of functional unit is key to fair comparisons.

6.5 *Define Reference Flow:*

6.5.1 Reference flow is the amount of product required to fulfill the prescribed task of the functional unit. Reference flow is uniquely defined by the functional unit, but is expressed as weight of material or product, and is used to normalize the inputs and outputs from the system in the subsequent steps.

6.5.2 The flows of all inputs, from raw materials, energy to land use will be normalized to the reference flow.

6.6 *Define Unit Processes and Product System Boundaries:*

6.6.1 Process flow sheets that describe the unit operations involved in making the products with process inputs and outputs are developed or acquired to describe the boundaries specified by Goal and Scope.

6.6.2 Internal flows will not be required in subsequent steps, but are usually needed to complete and check the process flow sheets. All process flows are quantified and normalized to the reference flow.

6.7 The definition of unit processes is often the most extensive step in this sequence. However, the required operations have been usually described in detail in the course of the plant or system design for plant construction. If the system is already operational, the design figures have been checked during process operation.

6.7.1 The process flow sheets must include items such as transportation, distribution, and maintenance unless excluded in the definition of the goal and scope of the process.

6.8 Resource allocation must be done under agreed-upon, transparent rules.

⁶ Lippiatt, B. C., "BEES 3.0 Building for Environmental and Economic Sustainability Technical and User Guide," NISTIR 6916, National Institute of Standards and Technology, Gaithersburg, MD, October 2002.

⁷ U.S. Environmental Protection Agency, "Tools for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI): Users Guide and System Documentation," EPA/600/R-02/052, U.S. EPA Office of Research and Development.

⁸ United Nations Environmental Programme, Division of Technology, Industry & Economics Production and Consumption Branch, 39 – 43 quai Andre Citroen, 75739 Paris, Cedex 15, France, www.unep.org/sustain/lcinitiative