Designation: E3066 – 16a

Standard Practice for Evaluating Relative Sustainability Involving Energy or Chemicals from Biomass[1]

This standard is issued under the fixed designation E3066; 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.

1. Scope

1.1 This standard practice provides a science-based methodology for evaluating the relative sustainability of options involving energy or chemicals derived from biomass. Options may involve products, processes, or projects.

1.2 The methodology includes setting goals and objectives, identifying stakeholders, selecting appropriate indicators, and evaluating the relative sustainability of options where at least one option is available from biomass.

1.3 The objectives are to facilitate fair comparison of options, focus efforts on practical indicators reflecting stakeholder priorities, and support continual improvement for more sustainable outcomes.

1.4 The purpose of this standard practice is not to declare something as sustainable or not sustainable but to help users assess, compare, and rank options based on specific goals and objectives.

1.5 *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]

E1705 Terminology Relating to Biotechnology

2.2 *ISO Standards:*[3]

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

ISO 14044 Life Cycle Assessment—Requirements and Guidelines

ISO 13065 Sustainability Criteria for Bioenergy

3. Terminology

3.1 For general terminology, refer to Terminology E1705.

NOTE 1—The user is advised that the definitions used by various industries, marketers, and regulatory bodies can differ from those in this standard. It is the responsibility of the user to ensure that the terms used in a particular context are clearly understood.

3.2 *Definitions:*

3.2.1 *biomass, n*—substance wholly comprised of living or recently living (nonfossil) material.

3.2.1.1 *Discussion*—Sometimes referred to as "renewable organic material," examples of biomass include whole or parts of plants, trees, aquatic organisms, animals, algae, and microorganisms.

3.2.2 *continual improvement, n*—a systematic, iterative process of identifying and evaluating options and selecting those that provide incremental improvements toward achieving defined goals and objectives.

3.2.3 *context, n*—the historical conditions, trends, and other forces that influence or define the measurement and interpretation of environmental, economic, and social indicators in a specific place and time.

3.2.4 *indicator, n*—specific, science-based, observable and measurable characteristic.

3.2.4.1 *Discussion*—Indicators can be used to assess conditions of a system, effects of activities on phenomena of concern, or to monitor trends in conditions over time. **(1)**[4]

3.2.5 *measure, v*—quantify the size, amount, or degree using a science-based approach and appropriate unit(s).

3.2.6 *science-based, adj*—applying principles and practices that employ the scientific method.

3.2.6.1 *Discussion*—The scientific method is a process of testing a hypothesis based on evidence and typically involves objective observation, experiment, critical analysis, verification, repetition, and induction.

[1] This practice is under the jurisdiction of ASTM Committee E48 on Bioenergy and Industrial Chemicals from Biomass and is the direct responsibility of Subcommittee E48.80 on Sustainability of Bioenergy and Industrial Chemicals from Biomass.

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[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.

[3] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

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

3.2.7 *stakeholder, n*—individual, group, or organization that can affect or be directly affected by the options being evaluated.

3.2.7.1 *Discussion*—The identification of stakeholders depends on the specific product, process, or project, and its context. Stakeholders may vary over time and can include regulatory bodies, customers, neighbors, employees, suppliers, and surrogates.

3.2.8 *sustainability, n*—aspirational concept denoting the capacity to meet current needs while maintaining options for future generations to meet their needs. **(2); (3); (4)**

3.2.8.1 *Discussion*—For additional information see 4.2.1.

3.2.9 *relative sustainability, n*—a comparison of two or more options that enables the evaluation of costs, benefits, and trade-offs that apply goals, objectives, and indicators within a specified context.

3.2.9.1 *Discussion*—for additional information see 4.2.3.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *assessment, n*—collecting data for the indicators selected in an evaluation plan.

3.3.2 *evaluation, n*—a systematic, iterative process for comparing options using prioritized science-based indicators and comparing the assessments while considering the trade-offs based on identified goals and boundary conditions.

3.3.2.1 *Discussion*—Within this standard practice, the evaluation may be referred to as the "evaluation plan" or simply "the plan."

4. Discussion of Concepts

4.1 Concepts used in this practice can differ from their use in other sustainability certification standards and schemes.

4.2 *Evaluating Relative Sustainability*

4.2.1 Sustainability does not imply a steady state or an absolute value; for human activity to be "sustainable," change or adaptation over time is required. To make the concept of sustainability operational, objectives must be defined within a specified context, stakeholders engaged, and consistent approaches applied to facilitate comparable, science-based assessments (**2-5**).

4.2.2 Environmental, economic, and social changes are inevitable. Staying on course toward goals entails an iterative process and adaptation to changing contextual conditions.

4.2.3 Evaluation of relative sustainability is supported by science-based analysis of environmental, economic, and social indicators of conditions associated with the options under consideration. The evaluation process includes documenting costs, benefits, and trade-offs among selected environmental, economic and social indicators.

4.3 *Context and Stakeholders*

4.3.1 Determining the context for evaluating the relative sustainability is a critical step. A decision or action that results in a more sustainable outcome under one set of conditions may not produce a more sustainable outcome under other conditions.

4.3.2 Defining context and identifying stakeholders depend on the proposed goals of an evaluation. Typically, the evaluation goals are directly linked to the options to be assessed. Objectives and context help establish the appropriate scope including the temporal and spatial boundaries. Assessments should focus on a scale that facilitates stakeholder engagement and enables researchers to collect and analyze data for activities that are causally linked to locally defined problems and observable values.

4.3.3 A clearly defined project purpose, addressing a clearly articulated problem, will help establish boundaries that facilitate constructive stakeholder engagement.

4.3.4 Stakeholder input is important to help identify and prioritize indicators and evaluation goals. Stakeholders also contribute to considering trade-offs, identifying sources of information, and supporting ongoing work (monitoring) toward continual improvement.

4.3.5 Transparent communication is a prerequisite for constructive stakeholder engagement. Transparency helps develop trust among parties and is a cornerstone for an evaluation of relative sustainability and the future monitoring and evaluation required for continual improvement.

4.4 *Science-based Indicators*

4.4.1 The assessment of options shall be based on relevant indicators. Separate standards should be cited and employed to assure replicable, science-based methods are used to measure each indicator.

4.4.2 This standard practice encourages the development of new science-based indicators for areas of stakeholder concern that are not yet adequately defined in standards.

4.4.3 See Appendix X1 for examples of science-based, measurable indicators.

4.5 *Comparison of Options*

4.5.1 Comparing the relative sustainability of options typically involves the interpretation of data related to past events and conditions (historical baseline) as well as goals and expectations about the future that are inherent when documenting and comparing the effects of a proposed option to the effects of an alternative or "business as usual" option.

4.6 *More Sustainable Outcomes*

4.6.1 An evaluation of relative sustainability is limited to identifying what appears to be a better way of achieving specified goals within a defined context and based on selected indicators. More sustainable outcomes necessarily consider the value of conserving non-renewable resources for future generations (**1**). The ability to compare options and guide decisions to support more sustainable outcomes is compromised if the assessment of one or more options relies on generalized data that do not capture the priorities and trade-offs involved in the specified context.

4.6.2 An evaluation of relative sustainability involves engaging stakeholders to identify priorities and build consensus around what being "more sustainable" means within the specified context.

4.7 *Continual Improvement*

4.7.1 This standard practice requires users to describe the mechanisms that will be applied to advance continual improvement. Because data about the past are limited and knowledge

of the future is still more uncertain, indicators should be selected and monitored in a manner that supports timely corrective actions.

4.7.2 The evaluation process and selected indicators should be reviewed and updated when new information and technological options offer opportunities to improve monitoring and analysis.

5. Summary of Practice

5.1 *Basic Principles for Evaluating the Relative Sustainability of Options*—Evaluating relative sustainability involves comparing assessments of two or more options involving a product, process or project. Each option shall be assessed using the following principles. One option could be the current conditions or status quo as a reference case.

5.1.1 Several basic principles improve the value of assessment outcomes for each option and thus the evaluation of the relative sustainability of the options.

5.1.2 *Transparency*—It is essential that the assessment of each option be documented in a way that allows for reproduction, with clearly communicated procedures and results.

5.1.2.1 The expectation of transparency does not stipulate that all information is made public. There may be situations where information could be considered proprietary or confidential under standard business practices. Confidential business information is not included under the transparency principle.

5.1.3 *Stakeholder Engagement*—The evaluation and associated assessments shall identify and engage stakeholders who are relevant to the evaluation scope and context.

5.1.4 *Timely Communication*—A system should be in place to share information on the status of priority indicators for options being assessed. Untimely reporting or delayed communication with stakeholders can hamper the effectiveness and value of the evaluation and increase the cost of corrective actions.

5.1.5 *Equivalent Treatment*—All assessments shall be developed and conducted using consistent approaches to examine effects relevant to the stated goals and in a manner that is replicable and facilitates objective comparisons.

5.2 *Six Steps for Assessing Sustainability Aspects of Each Option*—The following six steps shall be used to plan and conduct an assessment of each option. Fig. 1 provides a diagram of the evaluation plan.

5.2.1 *Step 1: Define the Evaluation Plan*

5.2.1.1 The evaluation plan shall clearly specify: who is initiating the plan; contact information for questions and communications about the plan; the time line; sources of

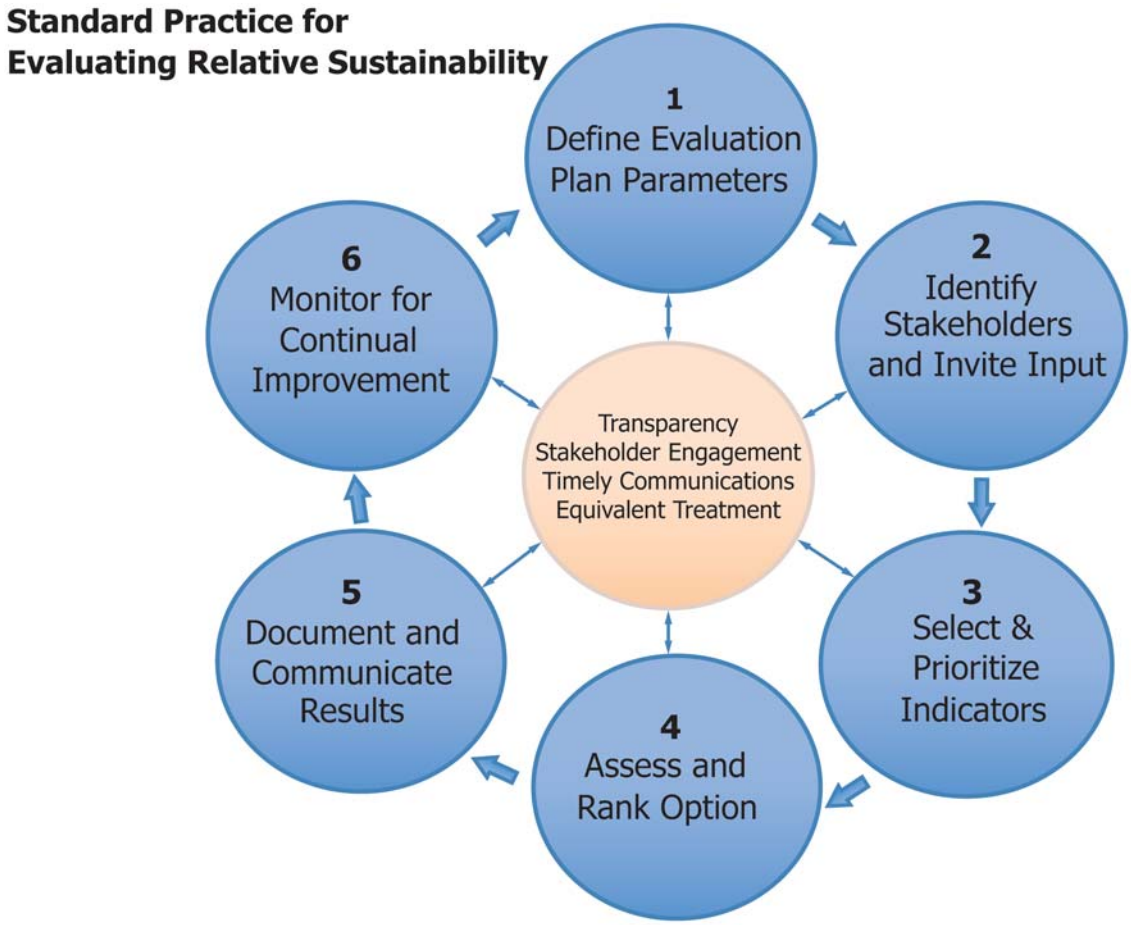

FIG. 1 Representation of Process for Evaluating Relative Sustainability

support to carry out the plan; the primary purpose and context of the plan; goals relevant to sustainability; and other aspects of the scope that are pertinent for subsequent steps, for example stakeholders, data sources, related surveys and studies, and special requirements or limitations imposed by external factors.

5.2.1.2 The evaluation plan shall propose the options to be compared including the reference case option.

5.2.1.3 The context description should include geographic areas and events associated with project activities; available data on current and historic conditions relevant to project objectives and activities; relevant regulatory requirements; sphere of influence and foreseeable effects associated with the activities; stakeholders and their concerns and priorities.

5.2.1.4 The scope of the evaluation should be achievable with available resources.

5.2.1.5 The plan and options to be assessed can be modified based on stakeholder engagement and new information discovered as the evaluation proceeds.

5.2.2 *Step 2: Identify Stakeholders and Invite Input*

5.2.2.1 Based on the plan purpose, objectives and context, and the scope of the evaluation, identify stakeholders and give them access to timely information on the evaluation plan and the options to be assessed.

5.2.2.2 Engaging stakeholders can be challenging because of the range of potential interest groups and the physical, financial and social-cultural barriers to constructive participation. If key stakeholders cannot participate, their perspectives should be represented through an alternate mechanism or surrogate.

5.2.2.3 Some sustainability indicators may involve global and regional issues such as climate, air, and water. Although evaluation processes call for stakeholder engagement, it is not practical for each assessment to reach all stakeholders interested in global issues. Therefore, it is reasonable to consider prior studies and third-party stakeholder consultations to identify stakeholder interests and priorities. The United Nations Sustainable Development Goals is an example of broad consultation regarding global issues and indicators (**6**). State and regional surveys may also provide relevant information on stakeholder concerns to complement the analysis of local priorities. Stakeholder engagement can help identify which options to assess, define desired future conditions, and provide feedback on communications related to assessment results and interpretation.

5.2.3 *Step 3: Select and Prioritize Indicators*

5.2.3.1 Define selection criteria for indicators based on the evaluation goals (**4**).

5.2.3.2 Consult stakeholders to document local priorities and concerns within the scope and context of the assessment. Stakeholders can offer valuable ideas, data, and other resources to help identify and measure relevant indicators. Involving them to develop unambiguous indicator definitions and to review selection criteria in terms of stakeholder values is recommended.

5.2.3.3 Document the data sets, analyses, research and monitoring required to support science-based indicators relevant to the proposed evaluation goals.

(1) Appendix X1 provides references for several examples of science-based measurable indicators. It is expected that additional standards will be developed to improve existing science-based measurable indicators and support new indicators as needed.

5.2.3.4 Rank proposed indicators in terms of indicator selection criteria.

5.2.3.5 Select the indicators to be used. Communicate the rationale for the selection and document how stakeholder priorities and concerns are considered.

5.2.3.6 Document the methods, definitions, units, and sources of information that will be used to determine indicator baselines, targets that reflect plan goals, and reported values over time. Document the planned monitoring schedules.

5.2.3.7 Assess plan options using the selected indicators. Carefully document the procedure used to define and measure indicator values under a reference case (also known as "counterfactual" or "business as usual" case).

5.2.4 *Step 4: Assess and Rank Options*

5.2.4.1 Determine whether available data and indicator values are valid and can be interpreted to guide decisions toward more sustainable outcomes (for example, provision of timely and useful information, (**4**)). If not, return to 5.2.3 (Step 3) to select a different indicator.

5.2.4.2 Document the measured values of each indicator under the options being compared.

5.2.4.3 Ensure methodology for computing each indicator value is clearly documented so that it is replicable by third parties.

5.2.4.4 Verify that the information collected enables a decision regarding the more sustainable options based on the defined context, goals, and criteria.

5.2.4.5 Rank each option based on the priority given each indicator in step 3 and the value obtained during the assessment of the options.

5.2.4.6 Review results with stakeholders and document any issues or trade-offs of high importance.

5.2.4.7 Identify areas for future adjustments to better address stakeholder concerns. Adjustments may involve modification to indicator definitions, measurement methods, monitoring, or reporting protocols.

5.2.5 *Step 5: Document and Communicate Results*

5.2.5.1 Document the comparison of the assessments for each option identified in Step 1 in terms of indicator values.

5.2.5.2 Communicate the results and highlight where costs and benefits of each option relative to the evaluation goals are distinct; this includes clearly illustrating any trade-offs across indicators for the options assessed. For example, present results in a matrix, interactive data set, or other tool that facilitates comparison of the computed indicator values under the different options assessed relative to the project goals or the direction of desired change.

5.2.5.3 Periodically repeat the assessment described in 5.2.4 (Step 4). The frequency of the repeated assessment will be based on project needs. Reassessment may be triggered by changes in markets, or by new information, technologies, or stakeholder concerns.

5.2.5.4 Review results with stakeholders periodically and identify contextual conditions or other significant considerations that have changed since the prior evaluation.

5.2.6 *Step 6: Evaluate to Support Continual Improvement*

5.2.6.1 *Monitoring Plan:* Document how the future performance of the selected option(s) will be monitored and communicated. Describe the plans for monitoring each indicator as the project proceeds in terms of schedule, responsibilities, and reporting. The monitoring plan and schedule for collecting data and reporting will vary depending on the specific indicator. This will be an iterative process to support continual improvement.

5.2.6.2 Document when and how information and analysis will be applied to guide short term and long term decisions.

5.2.6.3 Document the monitoring plan. This will be an iterative process to support continual improvement.

5.2.6.4 Document the changes and refinements achieved based on stakeholder input.

5.2.6.5 Determine if goals for more sustainable outcomes are being achieved. If so, consider how desired outcomes could be enhanced or accelerated. If not, reassess to determine why and undertake the actions needed to achieve the defined goals.

5.2.6.6 Review and refocus resources on the indicators and practices that contribute the most value in terms of guiding decisions toward ever improving outcomes.

5.2.6.7 If contextual conditions change significantly or monitoring indicates that goals are not being achieved, reanalysis should occur and the evaluation plan may need to reviewed and updated.

5.2.6.8 Identify gaps in the entire evaluation plan. This could lead to recommendations for new standards and science-based measurable indicators that to improve assessments.

6. Keywords

6.1 assessment; biomass-based products; chemicals; comparative sustainability; energy; relative sustainability

APPENDIX

(Nonmandatory Information)

X1. EXAMPLES OF SCIENCE-BASED MEASURABLE INDICATORS

X1.1 Sustainability considerations are frequently observed to consist of environmental, economic, and social elements often referred to as the "three pillars of sustainability." The state of sustainability science is constantly improving. The references below provide examples of efforts to conduct science-based assessments that have gone through some degree of peer review. However, because the concept of "sustainability" is nearly infinite in potential scope, there is a need to focus on priorities and clearly defined indicators. Just as the three pillars are interrelated, a number of the assessments identified below can cover elements of one, two, or all three pillars of sustainability.

X1.2 Examples of social and economic science-based indicators of sustainability (**1**).

X1.2.1 Fossil Energy Return on Investment (fossil EROI) measured by the ratio of amount of fossil energy inputs to amount of useful energy output (MJ) (adjusted for energy quality) (**7**, **8**).

X1.2.2 Work days lost due to injury measured by taking the average number of work days lost per worker per year.[5]

X1.3 Examples of environmental science-based indicators of sustainability (**3**).

X1.3.1 Greenhouse gases measured in carbon dioxide equivalents (according to ISO 13065, Section 6).

X1.4 Examples of relative sustainability—see US Department of Energy Bioenergy Technologies Office's Multiyear Program Plan.[6]

[5] More information available from the US Bureau of Labor Statistics, http://www.bls.gov/iif.

[6] http://www.energy.gov/sites/prod/files/2015/04/f22/mypp_beto_march2015.pdf

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