Designation: E3027 – 17

Standard Guide for Making Sustainability-Related Chemical Selection Decisions in the Life-Cycle of Products[1]

This standard is issued under the fixed designation E3027; 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 guide outlines sustainability factors for product manufacturers to consider when comparing alternative chemicals or ingredients across the life cycle of a product. Such an analysis could be used in product development, answering customer inquiries, or replying to regulatory requests, among others.

1.2 This guide integrates many of the principles of green chemistry and green engineering in evaluating the factors across the social (including human health), economic, and ecological attributes in the use of a particular material and potential alternatives in a particular product.

1.3 This guide provides an outline for the contents of a report of the results of the analysis, including an executive summary, detailed report, and retrospective.

1.4 This guide does not provide guidance on how to perform chemical risk assessment, alternatives assessment, life-cycle assessment, or economic analysis, or how the alternatives decision-making framework will be completed.

1.5 This guide does not suggest in what order the social, ecological, or economic attributes of sustainability should be evaluated or which one is most important. This is a decision of the company performing the decision-making evaluation.

1.6 *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 Standard:*[2]

E2114 Terminology for Sustainability Relative to the Performance of Buildings

2.2 *NSF/ANSI Standard:*[3]

NSF/ANSI Standard 61: Drinking water system components–Health effects

2.3 *Other Standards:*

US EPA Design for the Environment (DfE) Alternatives Assessment Criteria for Hazard Evaluation[4]

Clean Production Action GreenScreen for Safer Chemicals[5]

3. Terminology

3.1 *Definitions:* For definitions related to sustainability not defined within this guide, refer to Terminology E2114.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *alternatives decision-making framework, n*—process by which the alternatives are evaluated in any product life-cycle stage/phase with the goal of creating a product with an improved or less impactful result.

3.2.2 *assessment, alternative, n*—the activity of comparing the existing material and the material identified as a possible alternate.

3.2.3 *confidential business information, n*—business details including, but not limited to financial data, business relationships, product ingredients, or manufacturing processes that are unique to and held as proprietary to an organization.

3.2.3.1 *Discussion*—Confidential business information may also be referred to as trade secret information, especially as it relates to product formulation and manufacturing processes.

3.2.4 *data gap, n*—lack of information, quantitative data, modeled data, or estimations based upon read-across evidence used to determine the relative impact measure of an ingredient, process, or product.

---

[1] This guide is under the jurisdiction of ASTM Committee E60 on Sustainability and is the direct responsibility of Subcommittee E60.80 on General Sustainability Standards.

Current edition approved Jan. 1, 2017. Published January 1, 2017. Originally approved in 2015. Last previous edition approved in 2016 as E3027-16a. DOI: 10.1520/E3027-17.

[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 NSF International, P.O. Box 130140, 789 N. Dixboro Rd., Ann Arbor, MI, 48105, http://www.nsf.org.

[4] Available from US EPA, Safer Choice Program, Office of Pollution Prevention & Toxics, 1200 Pennsylvania Avenue, NW, Mail Code 7406-M, Washington, DC, http://www.epa.gov/sites/production/files/2014-01/documents/aa_criteria_v2.pdf. Safer Choice is the new name for EPA's Design for the Environment Program.

[5] GreenScreen is available from and a registered trademark of Clean Production Action, 1310 Broadway, Suite 101, Somerville, MA 02144, http://www.greenscreenchemicals.org/method/method-documents.

3.2.5 *economic assessment, n*—assessment which takes account of internal and external costs and benefits relative to the organization, generally those that can be valued in monetary terms.

3.2.5.1 *Discussion*—This could include a comparative cost study of production, material, and end-product costs of two or more ingredients, production methods, or products.

3.2.6 *exposure, n*—contact with a chemical, biological, or physical agent by an ecosystem or living organism, and the duration and level of intensity of that contact.

3.2.7 *feasibility, n*—overall ability of an alternative to be used based on human and ecological safety profiles, economics, performance, social benefits, compliance with regulatory requirements, and consumer acceptance.

3.2.8 *green chemistry and green engineering, n*—the philosophy of chemical research and design that encourages creating products and processes that minimize the use or generation, or both, of hazardous substances, hazardous process conditions, resources, energy, wastes, and water throughout the product life-cycle.

3.2.8.1 *Discussion*—Green chemistry and green engineering are often referenced separately. Refer to *Green Chemistry: Theory and Practice*[6] and "Design through the Twelve Principles of Green Engineering"[7] for a more detailed discussion of both.

3.2.9 *hazard, n*—a source of potential harm or damage to life, health, property, or environment due to exposure to a substance.

3.2.10 *impact, n*—an effect, which can be positive or negative.

3.2.10.1 *Discussion*—An impact can be across more than one aspect of sustainability. However, any specific impact should be addressed consistently within the analysis.

3.2.10.2 *impact, environmental, n*—changes on ecosystems or living organisms, other than humans, attributed to a chemical, biological, or physical interaction.

3.2.10.3 *impact, human health, n*—changes to the health or well-being of a group of individuals or the entire population attributed to a chemical, biological, or physical interaction.

3.2.10.4 *impacts, social, n*—effects of an activity on the well-being of a group of individuals, families, community, or other social group.

3.2.11 *life-cycle, n*—the stages of a product or process defined as: (*1*) the raw material production or acquisition stage, (*2*) the material transport stage, (*3*) the manufacturing stage (which includes transportation to the point of sale), (*4*) the use stage, and (*5*) the end-of-life stage.

3.2.11.1 *Discussion*—The terms stage and phase are used interchangeably. Additionally, the stages/phases defined in this guide may be changed by the user for his/her needs. For example, the transport of a finished product to the point of purchase by the user may be included in the use phase, the manufacturing stage, or its own stage/phase. This is completely acceptable within the parameters outlined for the practice of life-cycle assessment (LCA), so long as they are addressed consistently across the analysis being performed.

3.2.12 *manufacturing stage, n*—the segment of the life-cycle under the responsibility of the manufacturer, including activities such as formulation and production, through the transport of the final product to the point of purchase.

3.2.13 *product-chemical pair, n*—specific chemical ingredient or material that is being evaluated in a specific product and use application.

3.2.14 *read-across evidence, n*—data that is inferred from a chemical that is similar in structure to the chemical being considered that can be used to fill data gaps.

3.2.15 *risk, n*—the probability or chance of harmful effects to human or ecological health resulting from exposure to a stressor including any physical, chemical, or biological entity that can induce an adverse response.

3.2.15.1 *Discussion*—Risk is a function of hazard and exposure and therefore actions that impact either will impact risk.

3.2.16 *risk, residual, n*—potential danger that is theoretically possible after taking safety measures or precautions, or both, to minimize exposure to a stressor, such as a chemical, biological, or other agent.

3.2.17 *sensitive subpopulation, n*—a subset of the general population that are more likely to endure negative physiological impacts from exposure to a hazard than the average individual.

3.2.17.1 *Discussion*—Examples of affected subsets may include but are not limited to the elderly, children, or pregnant women.

3.2.18 *stressor, n*—a chemical, physical or biological agent that causes stress to an organism.

3.2.19 *sustainability attributes, n*—characteristics and their related effects that identify economic, social, health, and ecologic factors for consideration at each phase/stage of the life-cycle.

3.2.20 *use phase, n*—the use phase is the period in the product's life-cycle from when it is received by the final end user and placed into service until it reaches end of useful life.

4. Significance and Use

4.1 This guide outlines sustainability factors for manufacturers to consider when comparing alternative chemicals or ingredients across the life cycle of a product.

4.2 Methods exist for the evaluation of chemical hazards for product-chemical pairs. These methods are referenced in several regulatory, non-regulatory, and green building schemas and should be conducted as part of an analysis of this type.

NOTE 1—Evaluation methods include, but are not limited to, Clean Production Action's GreenScreen for Safer Chemicals,[5] The United States Environmental Protection Agency's Design for the Environment (DtE) Alternatives Assessment Criteria for Hazards Evaluation (Safer Choice) methodology and the National Academy of Sciences' *A Framework to*

[6] Anastas, P. and Warner, J., *Green Chemistry: Theory and Practice,* Oxford University Press, 1998.

[7] Anastas, P.T., and Zimmerman, J.B., "Design through the Twelve Principles of Green Engineering," *Env. Sci. and Tech.*, 37, 5, 94A-101A, 2003.

Guide Selection of Chemical Alternatives.[8] Regulatory schemas include laws such as the *Safer Consumer Products Rule*[9] in California or the *Registration, Evaluation, and Authorization of Chemicals* (REACh)[10] regulations in Europe. Green building schemas include the *Leadership in Energy and Environmental Design (LEED)*[11] system by the USGBC, which references these indirectly through third-party certifications. However, neither these assessment tools nor the various schemas that reference them have set guidance for using the data in making decisions on which products and ingredients are ultimately the most sustainable.

4.3 Similarly, many tools exist for measuring economic viability, such as value-models and cost analysis. There are also many tools and techniques for measuring social acceptance of products such as sales trends, voice of the customer and many other types of surveys.

4.4 This guide acknowledges the need for determining a baseline for comparing the performance (environmental, economic, and social) of an existing product-chemical pair in a product with the possible/potential alternatives. As such, when using this guide, companies shall use the same study boundaries for the original baseline case and for all alternative options under assessment. Further, when feasible, the same assessment tools should also be used for all options being analyzed.

4.5 Sustainability is a very holistic and encompassing concept. As such, many factors cross all three attributes of sustainability. While factors may be assigned one way in this guide, it is recognized the user has discretion to assign them to whatever attribute(s) they deem appropriate when performing this analysis. However, the user should consistently categorize among all analyses for the purpose of easy comparison.

5. Social Considerations

5.1 *General:*

5.1.1 This section provides guidance on choosing the social sustainability factors that may be used as input into the alternatives decision making.

5.1.1.1 The alternatives assessment should be used as input into a risk assessment or risk assessments to determine the most relevant of human health impacts for employees, users, and other pertinent individuals. An example of such a risk assessment is NSF/ANSI Standard 61: Drinking Water System Components–Health Effects for potable water systems and applications, though many other assessment methods exist for other industries.

5.1.1.2 Risk should be considered at each of the stages of the life-cycle as factors such as exposure and hazard may differ in each phase.

5.1.2 Social considerations include applicable regulations related to labor, worker health and safety, and other related factors.

5.1.3 A list of social considerations of the alternatives should be created for each life-cycle stage taking into consideration stakeholders, corporate culture, and social norms of the market.

NOTE 2—The list of social sustainability factors will differ from one company to another as corporate culture/values are never identical. A company participating in a specific market space can define for itself what social considerations matter but in some manner internal and external health impacts must be considered.

5.1.4 Social sustainability factors of importance will differ from product to product and in various stages of the product life-cycle.

5.1.5 Identification of some of the social sustainability factors that are of importance may be accomplished via one of many methods, such as through internal and external stakeholder feedback including the community, voice of the customer, or many sales/marketing tools discussed in marketing texts. Those undertaking this analysis should obtain feedback from internal and external stakeholders at each stage of the life-cycle as input to the assessment.

5.1.6 While there are many sustainability issues to consider, one that can significantly impact social factors is raw material availability. Sustainability inherently requires the considerations of ensuring that raw material availability for the needs of future generations is met.

5.2 *Considerations of Social Sustainable Factors at the Raw Material Acquisition Stage:*

5.2.1 While social considerations impact many groups of individuals, at this phase they will revolve disproportionately around the worker. Such sustainability factors may include wages, safety and health of workers, child-labor, slave labor, worker benefits, labor practices, the politics of domestic versus foreign sourcing, and other labor-centric issues.

5.2.1.1 Worker health and safety should include items such as access to personal protective equipment, availability of emergency care, as well as safe management of materials as dictated by risk of exposure and potential impacts.

5.2.2 Socio-political conditions in which raw materials are most commonly acquired, including extraction, mining, or harvest, may be an additional consideration. Areas with issues such as human rights concerns, oppressive regimes, and known areas of terrorist activity should be considerations in determining a material's viability to any corporation.

5.3 *Social Considerations at the Material Transport Stage:*

5.3.1 Safe management of raw materials and wastes should be a consideration in the evaluation at the transport stage of a raw material to protect workers and the general public. Raw materials posing health (that is, toxicity) or physical (for example, flammability or corrosiveness) risks should be evaluated in the assessment.

5.3.2 Additional considerations may involve transport method(s). For example, access to markets, transport connectivity, safety of method and other factors are important considerations as an organization considers how to transport raw materials to production facilities.

[8] *A Framework to Guide Selection of Chemical Alternatives*, The National Academies Press, Washington DC, 2014.

[9] *Calilfornia Assembly Bill 1879 – The Safer Consumer Product Act,* http://www.leginfo.ca.gov/pub/07-08/bill/asm/ab_1851-1900/ab_1879_bill_20080911_enrolled.html.

[10] *Registration, Evaluation and Authorization of Chemicals (REACh)*, The European Chemicals Agency, http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02006R1907-20140822.

[11] Version 4 available from United States Green Building Council (USGBC), http://www.usgbc.org/leed#v4.

5.4 *Social Considerations of the Manufacturing Stage:*

5.4.1 Social sustainability factors may differ greatly depending upon other factors such as employee-employer relations at a given facility or geographic location of manufacture.

5.4.2 While there can be variation, manufacturing and formulating companies may often find they are using the same or similar sustainability factors to assess social considerations for this phase as companies who acquire raw materials used.

5.4.3 Product type may also have a significant bearing on which factors are of importance. Individual product types will have their own specific issues. Organizations built upon a culture of using specific technical platforms may find it challenging to change technologies to accommodate social considerations.

5.4.4 As with 5.2, worker safety issues should be of high importance in the manufacturing stage.

5.5 *Social Considerations of the Use Stage:*

5.5.1 User or intended market perceptions and social mores will be factors for consideration.

5.5.2 Factors such as age, gender, sensitive populations, and the cultural leanings of the intended user are included in the social considerations.

5.5.3 Many organizations may find this to be the area in which significant external stakeholder input is used extensively. Such input can be gathered in many ways, including through marketing exercises such as voice of the customer, market studies, and related concepts.

5.5.4 The user input may heavily influence the other factors of this analysis.

5.5.5 Potential social sustainability factors may differ widely and be product and market specific. For example, some markets and products may dictate specific durability or efficacy criteria, whereas other markets may place importance in other sustainability factors, such as rapid access to the most advanced technology with its collateral shorter product life span.

5.5.6 Organizations may also wish to consider unintended uses or consequences of using a product and how individual ingredients may contribute. Mitigation factors such as special packaging or precautions for the user should be considered in such instances to minimize risk and their need weighed in the overall analysis.

5.6 *Social Considerations of End of Life:*

5.6.1 As products differ, so will end-of-life considerations.

5.6.2 Products that are single use or disposable in nature or intent may have different concerns than those that are designed for extended useful life.

5.6.3 Recyclability, ease of disposal, including the hazardous nature of waste, or the ability to repurpose or compost a product or components are factors that may be important, as well as the availability of take-back programs.

5.6.4 The conditions under which the final disposition processes occur and their impact upon the health of employees and nearby community in this phase/stage, as well as the fair treatment of employees, should be considered.

6. Economic Considerations

6.1 *General:*

6.1.1 Economic considerations include adherence to all local financial laws and regulations in all areas in which business activities occur.

6.1.2 A list of all economic considerations for the alternatives within the control of the manufacturer should be created for each life-cycle stage consistent with the system boundaries defined in the original baseline for use.

6.1.3 While all life-cycle phases/stages and products have economic considerations, the phase(s)/stage(s) of most importance will differ from product to product or even one product of the same kind to another.

6.1.4 Materials that are considered commodities versus specialty materials may have much different economic sustainability factors.

6.1.5 At each phase, the economics, including costs, of ensuring environmental protection through process controls and worker health benefits, compensation, and safety should be included.

6.1.5.1 Risk assessment and alternatives assessment information should dictate the equipment needed for appropriate handling at each stage/phase.

6.1.6 Both micro and macroscale economic factors should be considered.

6.2 *Economic Considerations at the Raw Material Acquisition Stage:*

6.2.1 Economic considerations should include employee-related expenses such as personal protective equipment. Such considerations may include fulfilling needs identified as critical for the social sustainability factors when it comes to employees and workers harvesting raw materials.

6.2.2 Operational expenses are another major economic factor. The equipment and means of harvesting one material versus another may significantly impact the cost of acquisition.

6.2.3 Availability and accessibility of the raw material is a major economic consideration. Raw materials with limited availability or accessibility may cause a final product to be too expensive to make and sell in the short-term.

6.3 *Economic Considerations at the Material Transport Stage:*

6.3.1 The means and distance of transport will have significant costs on the raw material economics.

6.3.2 The nature of the material and its packaging will impact transport. For example, dangerous goods may require special handling or insurance.

6.3.3 Additional considerations may involve transport methodology of choice. For example, an organization may choose to use a mode of transportation where they can negotiate better rates or gain greater fuel efficiency and still meet safety and timing requirements.

6.4 *Economic Considerations of the Manufacturing Stage:*

6.4.1 Investment in capital equipment, if needed, can be an economic factor in determining what to produce and with which materials. Special handling equipment may add to these needs.

6.4.2 While there can be variation, companies may find they are using many of the same factors found in raw material acquisition.

6.4.3 Economics associated with the need for manufacturing times, processing, as well as considerations associated with energy and water inputs used because of each alternative. One may find these are also ecological factors as well, depending on the company's specific factors of most concern.

6.5 *Economic Considerations of the Use Stage:*

6.5.1 Perceived and actual value to the end-user is a significant consideration in this phase.

6.5.2 Considerations such as the number of expected uses versus cost, durability, the efficiency of the product, the need for additional products to use with the product in question, and other secondary economic factors should be included.

6.5.3 Many organizations may find that analyses for this phase require significant stakeholder input through marketing exercises such as voice of the customer and market studies to estimate consumer preferences and behavior.

6.5.3.1 Potential economic sustainability factors may differ widely and may be product and market specific. For example, some markets and products may dictate very specific cost points or performance criteria that will alter price; whereas, others may use ecological attributes such as energy and water consumption, generation of greenhouse gases, carbon footprint, and others.

6.5.3.2 The end-user input may heavily influence the other factors that should be included across all life-cycle stages and all three attributes of sustainability.

6.6 *Economic Considerations of End of Life:*

6.6.1 End-of-life considerations differ with products.

6.6.2 Disposal methodology will impact economics. For example, if a product is considered hazardous per environmental regulations, there may be additional handling and disposal costs incurred by the user, local tax base, or producer.

6.6.3 Compostability, recyclability, biodegradability, take-back programs and the ability to repurpose a product or proper disposal costs will have economic considerations. For example, while it may be viable economically to recycle a specific material in some geographic areas, the lack of collection or processing infrastructure, lack of a viable market to use the recycled or reclaimed products or other factors may make it infeasible in others.

7. Ecological Considerations

7.1 *General:*

7.1.1 Ecological considerations of alternatives are to be included in the decision-making framework coupled with other factors the organization deems appropriate for their goals, such as the product type, the range of usage, and other product-specific characteristics.

7.1.1.1 An environment-centric risk assessment using ecological toxicology data should be used for each life-cycle phase considering the appropriate modes of entry into the environment.

NOTE 3—There are many tools and methods available for doing such assessments. For comparability, the same method should be used for each alternative being considered or rationale being supplied for circumstances where methods differ.

7.1.2 Ecological considerations include compliance with all applicable laws related to environmental protection.

7.1.3 A list of ecological factors should be created for each life-cycle stage based upon the system boundaries and each alternative compared. Using impact categories commonly considered in life cycle assessments may provide a basis for consideration.

7.1.4 While all life-cycle phases/stages have ecological considerations, the phase(s)/stage(s) of most importance will differ from product to product or even one product of the same kind to another but should, at minimum, include the evaluation of net energy consumption, net water consumption, and emissions/discharges to the environment.

7.2 *Ecological Considerations at the Raw Material Acquisition Stage:*

7.2.1 The overall effects on the local environment are of consideration in raw material acquisition. Effects include, but are not limited to, severity, longevity, and extent of impact.

7.2.2 Ecological impacts deriving from the intrinsic characteristics of a raw material as well as the method by which it is attained should be considered. Many raw materials have several means of attainment, some of which may have fewer or less significant impact than others.

7.2.2.1 The various raw materials being considered should be compared by all viable routes of raw material acquisition to ensure completeness.

7.2.3 Specific ecological factors may differ greatly depending upon the type of resource.

7.3 *Ecological Considerations at the Material Transport Stage:*

7.3.1 The means of transport coupled with distance can have significant ecological impacts.

7.3.2 The nature of the material will impact factors such as material handling during transport, packaging choices, distribution options, delivery to customer, and other related factors. Goods especially harmful to the environment may require special handling and possibly be restricted in transport method. This could generate an ecological cost of the product life-cycle that may offset any benefit.

7.3.3 Additional considerations may involve net production of carbon dioxide and other greenhouse gases associated with transport as an organization considers means of transport.

7.4 *Ecological Considerations of the Manufacturing Stage:*

7.4.1 Existing equipment capabilities may need to be considered. The need for additional environmental controls, can be an ecological factor in determining what to produce and with what materials. Special handling equipment may add to these needs.

7.4.2 While there can be variation, companies may often find they are using many of the same sustainability factors as used for raw material acquisition considerations and the transport part of this stage from the manufacturing plant to the point of purchase.

7.4.3 For products that transform significantly during manufacturing through reactions or other transformation processes, considerations shall be made for the intermediate and final product as well.

7.4.4 Disposal and impact of by-products or wastes from one product-chemical pair versus another should be considered along with the quantity as relative ecological harm may differ greatly.

7.4.5 Additional impacts such as energy use in the manufacturing, thermal pollution, water use and waste water, should be considered as appropriate.

7.5 *Ecological Considerations of the Use Stage:*

7.5.1 During the use phase, a variety of factors should be identified and evaluated including how the selection of a particular alternative affects the amount of product used (for a consumable product) or product useful life (for a durable product), how an alternative may affect other ecological issues associated with the product use (for example, energy consumption), the need for additional products to use with the product in question, and other secondary ecological impacts.

7.5.2 Companies may find the analysis of the use phase to be the area in which user input through marketing exercises such as use habit observation, voice of the customer, or other methods found in marketing texts may support decision making.

7.5.3 The user input may influence the other factors across all life-cycle stages and all three attributes of sustainability.

7.6 *Ecological Considerations of End of Life:*

7.6.1 As products differ greatly, so will end-of-life considerations.

7.6.2 Disposal management is likely a major factor to consider. For example, one should consider if a product or its components is considered hazardous by regulation, or needs special handling, such as incineration or traditional landfilling, if they are not recyclable, reusable, or compostable.

7.6.3 The release of emissions or substances upon decomposition or reclamation should be considered. Some product-chemical pairs may create or release emissions or substances that pose the potential for ecological impact. Similarly, if a material is not easily recycled, reclaimed, biodegraded, composted, taken-back or otherwise meets end-of-life in what may be considered a more ecologically preferable manner in many geographic areas, then that needs to be considered in the analysis.

8. Reports—Decision, Analysis, and Retrospective

8.1 *Decision Report:*

8.1.1 The decision regarding the selection of an alternative should start with a concise statement, a baseline of data, and an array of factors used in the decision-making process. These elements are an executive summary of the analysis report and generally would be free of confidential business information.

8.1.2 The decision statement should include the criteria for selecting an alternative that best satisfies the desired factors identified.

8.2 *Analysis Report:*

8.2.1 The analysis report should be considered a full, detailed report that can be used for internal project documentation, submitted for regulatory reporting or used for certification per a voluntary sustainability performance standard.

8.2.2 Provide detailed outlines, calculations, and rationale for all analyses. The calculations should be based upon the same system boundary definition; include baseline data of the original product-chemical pair for comparison, a list of the factors for comparison, and the criteria for making decisions within the decision-making process.

8.2.3 Depending upon the audience, it may be acceptable to use generic identifiers for specific items such as raw material names, Chemical Abstracts Services Registry Number (CAS #), or other identifiers specific to the ingredients or finished products being analyzed to protect confidential business information.

8.2.3.1 In such cases, general information should still be provided. For example, if a material is a cyclic ketone being considered for a new application, the name and CAS # could be withheld, but the material could be identified as a “cyclic ketone” or by its functional role. The description should be sufficient such that a knowledgeable reader can retrace the steps in the assessment and validate the basis for its conclusion.

8.2.4 All alternative assessments and the related ecological and human toxicological analyses shall be provided, again allowing for the ability to protect confidential business information such as specific names if warranted.

8.2.5 All analyses should cover the five life-cycle phases across the three attributes of sustainability.

8.2.6 The analysis should address apparent data gaps in the alternatives decision-making framework, not only in the alternatives assessment or risk assessment, but also in other parts of the decision-making process, including economic analysis. Rationalization and assumptions made in addressing the missing data should be explained. The implications of the data gaps to the decision-making process should be presented.

8.3 *Retrospective:*

8.3.1 A retrospective is key in continual improvement of the sustainability of a product.

8.3.2 The retrospective may include areas of improvement that may inform the development or use of future generations of products or technologies derived from products.

8.3.3 The retrospective should also include a review of what additional information would result in modifying the overall findings of the decision-making process. Is it efforts to gather specific data gaps? Is it a better understanding of the market and factors that influence market changes and consumer behavior? Is it a regulatory change?

8.3.4 A retrospective should also include an objective review of the analysis process and how it may be improved for performing future evaluations.

9. Keywords

9.1 alternatives assessment; chemical selection; green chemistry; green engineering; life-cycle; sustainability attributes