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Life Cycle Impact Assessment for the Building Design and Construction Industry

By Jane Bare and Thomas Gloria, PhD

You can measure chemical emissions and construction wastes by the ton, but weight alone won't tell you how or where the emissions and waste may harm humans or the environment. If you can apply the metrics of life cycle impact assessment, however, you can understand a great deal more about how much harm might come to humans and the environment from the emissions or waste—harm in the form of global climate change, reduction in the ozone layer, increased risk of cancer in humans, and the depletion of finite resources such as fossil fuels.

The most effective way to assess the potential for long-term improvements for human health and the environment is through the use of consistent metrics within a comprehensive decision-making framework. Life cycle assessment is the framework embraced by many leading sustainability professionals. LCA can be used to evaluate the potential for impacts at all of the points along the process of design, construction, maintenance, use, and disassembly. Within life cycle assessment, life cycle impact assessment represents the consistent metrics.

Life cycle impact assessment is the tool that life cycle practitioners use to see which chemical emissions have the greatest potential to cause harm and in what form that harm may occur. Without this tool, releasing a pound of mercury to the environment would look just like releasing a pound of sand. Many aspects of this tool were formed as little as a decade ago. Although there is still room for improvement, LCIA can now distinguish a full spectrum of areas of concern.

The Basics of LCIA

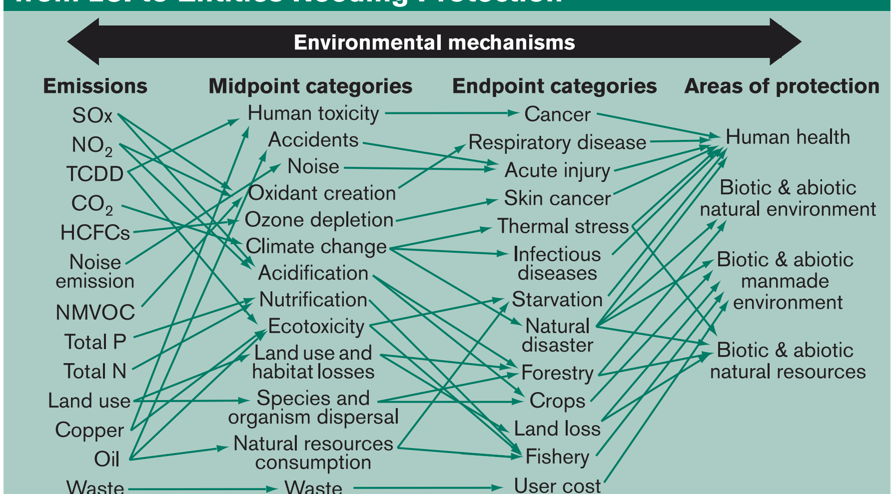
Life cycle impact assessment creates the connection between the life cycle inventory (the emissions and materials used) and the components of our society that we wish most dearly to protect—human health, the natural environment, the man-made environment (not just buildings and homes, but also things like crops), and natural resources. As shown in the accompanying figure, LCIA attempts to capture the continuum of all environmental mechanisms. The arrows in this figure should not be construed as describing environmental mechanisms with absolute certainty, but they do indicate that, at minimum, there is some quantitative evidence and qualitative understanding of the links shown.

Across this continuum there are two general approaches to categorize life cycle impacts—a midpoint approach and an endpoint approach.

The midpoint approach starts from the emissions identified by a life cycle inventory and takes these as input to models that bring us further along the environmental mechanism of accepted impact categories. One of the most well-known midpoint indicators is global warming potential, a measure of a chemical's potential to affect the world's climate. Global warming potential is typically expressed in terms relative to carbon dioxide's contribution to climate change, usually referred to as "CO_2 equivalents." The LCIA results expressed in terms of midpoint variables are typically used to support decision making, as they are readily understood and their scientific basis is well established.

In contrast, endpoint (or "damage assessment")

Impact Assessment: Making the Connection from LCI to Entities Needing Protection



Source: Jolliott O et al. (2004): "The LCIA midpoint-damage framework of the UNEP-SETAC life cycle initiative," Int J of LCA 9 (6) 394-404.

models link emissions and resources used to endpoint indicators. Endpoint models typically have a higher level of uncertainty, since they include more assumptions to quantify the impacts. Damage assessments also attempt to represent many more links across the network of environmental mechanisms, and in the absence of data to support these calculations, damage assessments tend to be less comprehensive—those endpoints which are difficult to calculate simply drop out.

In addition to the impacts related to chemical emissions, LCA typically keeps track of resource depletion. Resource depletion impact assessment includes an accounting of the amount of a material used and the amount of material which remains, while also considering quality and the potential for substitution. Typical resource depletion categories include fossil fuel use, land use, water use, and mineral use. Some LCA experts also choose to keep track of the energy consumed within the individual life cycle stages. Other methodologies make a distinction between sources of energy (e.g., wind, fossil fuels), thus recognizing the scarcity of some fuel sources.

In more formal terms, LCIA is one of the four iterative steps of LCA as outlined by the ISO standards:

1) Goal and Scope
2) Life Cycle Inventory
3) Impact Assessment
4) Interpretation

Within the Impact Assessment step, there are seven generally accepted elements (see chart) pertaining to the process of conducting a life cycle impact assessment.

The first three elements of LCIA—selection, classification, and characterization—are mandatory.

Selection pertains to the identification of relevant impact categories. The impact categories selected should be consistent with the goal and scope and reflect a comprehensive set of environmental issues related to the product system being studied. Although broken out as part of the impact assessment phase of an LCA study, the selection of impact categories is decided at the very beginning, when the goal and scope of the study are being determined and before the collection of the supporting data begins. Selection of impact categories determines to a great extent data collection needs and the boundary of the conclusions that can be made.

Classification involves assigning the emissions and resources identified by the LCIA to specific impact categories (global warming, ozone depletion, ecological toxicity, etc.) In practice, the characterization method selected determines the classification. This is an area that requires particular attention by the LCA consultant, as naming conventions can cause classification mismatches or may cause some chemicals to drop out.

Characterization is where impact assessment results are calculated. The actual calculation of impact involves multiplying each environmental intervention (emissions in mass) by the corresponding characterization factor (effect per unit of emission), and summing the results within each impact category. Characterization factors are essentially a rank measure of potential harm by a chemical within an impact category.

For example, carbon dioxide has a global warming potential (GWP) of 1, while methane has a GWP of 23. This means that one molecule of methane has the potential to affect climate change with a potency 23 times that of carbon dioxide. Characterization factors are based on underlying characterization models set to specific conditions—climate, soil type, time frame, etc.

The remaining four elements—normalization, grouping, weighting, and data quality—while optional in an LCIA, can provide valuable insights.

Normalization involves the calculation of relative contribution to impact to a reference boundary, typically a region or country. For example, results obtained for GWP are normalized to all emissions that occur in the U.S. on a per capita basis. Normalization is typically done to obtain congruent (i.e., equal) representation of impact categories when proceeding with further grouping or weighting of results.

Grouping is simply the assignment of impact categories to groups of similar impacts or ranking categories in a given hierarchy—high, medium, and low priority.

Weighting is a more formalized process of grouping that involves the assignment of relative values or weights to different impacts, allowing integration across all impact categories. The "weights" in the weighting step are typically determined by a panel of experts or stakeholders.

Data quality analysis is done to better understand the significance, uncertainty, and sensitivity of LCIA results.

Detailed Elements of Life Cycle Impact Assessment (ISO 14042)

Selection Determination of relevant impact categories, category indicators, and characterization models

Classification Assignment of life cycle inventory results

Characterization Calculation of category indicator results

Normalization Calculation of the magnitude of category indicator results relative to reference

Grouping Assignment of impact categories to groups of similar impacts

Weighting Assignment of relative values or weights to different impacts, allowing integration across all categories

Data quality check Analysis of the significance, uncertainty, and sensitivity of LCIA results

Source: ISO 14042 (2000) Environmental Management – Life cycle assessment – Life cycle impact assessment, International Organization of Standardization, Geneva, Switzerland.

Impact Categories in TRACI

1. Acidification
2. Ecotoxicty
3. Eutrophication
4. Fossil fuel depletion
5. Global warming
6. Human health cancer
7. Human health criteria
8. Human health noncancer
9. Ozone depletion
10. Smog formation

Midpoint Methods

EDIP97/2003
http://ipt.dtu.dk/~mic/Projects.htm

Dutch LCA Handbook
www.leidenuniv.nl/cml/ssp/projects/lca2/lca2.html

USEPA TRACI method
www.epa.gov/ORD/NRMRL/std/sab/iam_traci.htm

Endpoint Methods

Eco-indicator 99
www.pre.nl/eco-indicator99/

EPS 2000d
http://eps.esa.chalmers.se/

A Look at the U.S. EPA's TRACI

For the past 10 years, the US EPA has focused on developing the best possible impact assessment tool for life cycle impact assessment, pollution prevention (known as P2), and sustainability metrics for the U.S. This research effort is called TRACI, which stands for the Tool for the Reduction and Assessment of Chemical and other Environmental Impacts.

The impact categories in TRACI (see list) were selected based on their level of commonality with existing literature in this area, their consistency with EPA regulations and policies, their current state of development, and their perceived societal value. The traditional pollution categories of ozone depletion, global warming, human toxicology, ecological toxicology (ecotoxicity), smog formation, acidification, and eutrophication were included within TRACI because EPA programs and regulations recognize the value of minimizing effects from these categories. Criteria pollutants were preserved as a separate human health impact category to allow a modeling approach that could take advantage of the extensive epidemiological data associated with the impacts of criteria pollutants.

The TRACI software allows the storage of inventory data, classification of stressors into 10 impact categories, and characterization for the listed impact categories.

Consistency with previous modeling assumptions (especially within the EPA) was important in the development of the impact assessment characterization underlying every category. The human health cancer and noncancer categories were heavily based on the assumptions made for the US EPA Risk Assessment Guidance for Superfund. The EPA's Exposure Factors Handbook was utilized to make decisions related to the various input parameters for both of these categories as well. Another example of consistency with EPA modeling assumptions includes the use of the 100-year time frame reference for global warming potentials.

The EPA decided that TRACI should be primarily a midpoint model because this is the level that enjoys the greatest consensus. With endpoint modeling, moreover, some of the endpoints are lost when extrapolating to damages, since they cannot be calculated.

LCIA in Building Design and Construction

Life cycle impact assessment is already being used by the green building community. In the United Kingdom, the Building Research Establishment has developed a product rating system, the Green Guide to Industry, using the Dutch Handbook (CML) Method. In the U.S., TRACI is embedded in the National Institute of Standards & Technology's Building for Environmental and Economic Sustainability (BEES 3.0) method.

More recently, the U.S. Green Building Council has initiated an investigation of applying LCA into the Leadership in Energy and Environmental Design (LEED) rating system. Workgroup B of the task force was charged with selecting the most appropriate LCIA methodology for inclusion within LEED. Criteria deemed important by the task force included:

- Relevance to building product systems
- Availablity of U.S. characterization factors (not including GWP and ozone depletion potential)
- Site specificity selection (e.g., bioregions)
- General scientific validity of the method
- Relevance to the green building community
- Comprehensive set of environmentally important impact categories
- Identifies endpoints of concern and considers linkages with inventory results
- Contains U.S. normalization database

Based on its evaluation of the above criteria, Workgroup B recommended to the LEED task force that TRACI be used as the impact assessment methodology of choice. By consensus vote, the task force adopted the use of TRACI within LEED.

As we have seen, life cycle impact assessment is the tool that life cycle practitioners use to see which chemical emissions and resource uses have the greatest potential to cause harm. With this perspective, LCIA methods are able to assist decision makers to appropriately prioritize the most beneficial options to reduce burden to humans and the environment. The green building community has already started using LCIA methods to measure product performance and this use of LCIA is likely to increase. Tools like the U.S. EPA's TRACI can be used to do an LCIA for individual building materials or for whole buildings.