The Toolkit Approach to Sustainability

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Do you grab the screwdriver when you want to drive a nail? How about grabbing the hammer to tighten the nut on a bolt? Of course not! You go to the toolkit and pick the right tool for the job at hand. The same logic applies to proper use of Life Cycle Assessment (LCA).

The reality is that LCA is one essential tool, in fact one of the oldest, in a toolkit stocked with complementary tools that aid in evaluation of the potential environmental impacts of a product system throughout its life cycle. This article does not address every tool in the sustainability toolkit that can and should complement life cycle tools. For example, risk assessment approaches can be applied at the environmental, ecological, or public health levels. Pharos is an example of a tool for researching and specifying products in terms of toxicity levels, and GreenSpec Directory is a guide to environmentally preferential building products that helps users find and access environmentally related information from a variety of sources. Forest certification systems are another example of tools that complement LCA by focusing on site-specific effects that are not easily encompassed by LCA. It is highly likely that we will see similar certification tools for mining and other extraction industries. And we can't overlook the tools for assessing buildings from a variety of perspectives – energy performance, site selection, materials, water use, etc. – with LEED and GreenGlobes as the North American examples of a growing international list of building rating tools.

In the sections that follow, the toolkit concept is explored in greater detail from the perspective of life cycle approaches in general, starting with an overview of LCA including a brief history of the methodology. Subsequent sections then deal with tools related to the economic and social legs of the basic three-legged stool analogy for sustainability. The focus here tends to be on building products and buildings, but the concepts, if not all the details, equally apply to other product categories.

Life Cycle Assessment

LCA is an analytical method used to comprehensively quantify and interpret energy and material flows to and from the environment over the entire life cycle of a product, process, or service. As defined in two key international standards, ISO 14040:2006 and ISO 14044:2006, LCA involves "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle."[1] The ISO standards describe an iterative four-stage phased methodology framework for completing an LCA, as shown in the figure (Figure 1).

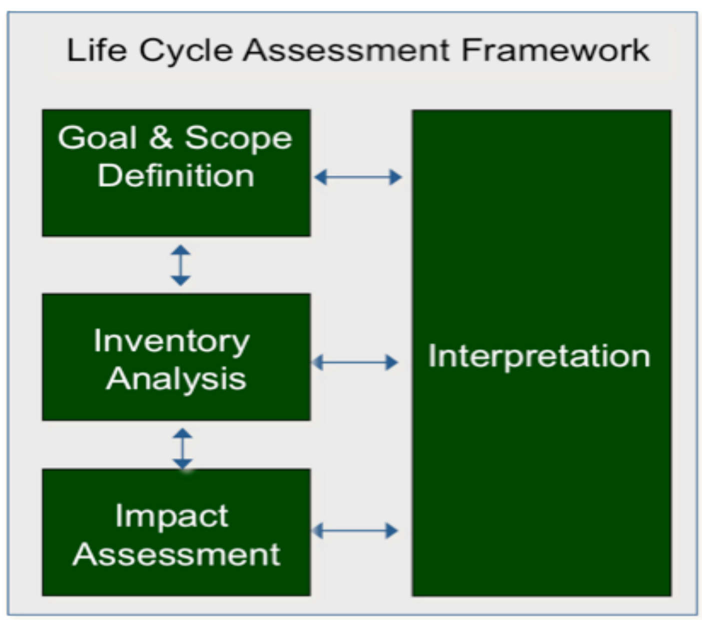

Figure 1. Stages of an LCA as per ISO 14044:2006

[1] ISO 14040:2006. Environmental Management – Life Cycle Assessment – Principles and Framework. ISO 14044:2006. Environmental Management – Life Cycle Assessment – Requirements and guidelines.

Goal and Scope Definition
An LCA starts with an explicit statement of the goal and scope of the study, which sets out the context of the study and explains how and to whom the results are to be communicated. This is a key step and the ISO standards require that the goal and scope of an LCA be clearly defined and consistent with the intended application. The goal and scope document therefore includes technical details that guide subsequent work.

Life Cycle Inventory
Life Cycle Inventory (LCI) analysis involves creating an inventory of flows from and to nature for a product system. Inventory flows include inputs of water, energy, and raw materials, and releases to air, land, and water. To develop the inventory, a flow model of the technical system is constructed using data on inputs and outputs. The model is typically scoped with a flow chart that includes the activities that are going to be assessed in the relevant production system and gives a clear picture of the technical system boundaries, as illustrated in Figure 2.

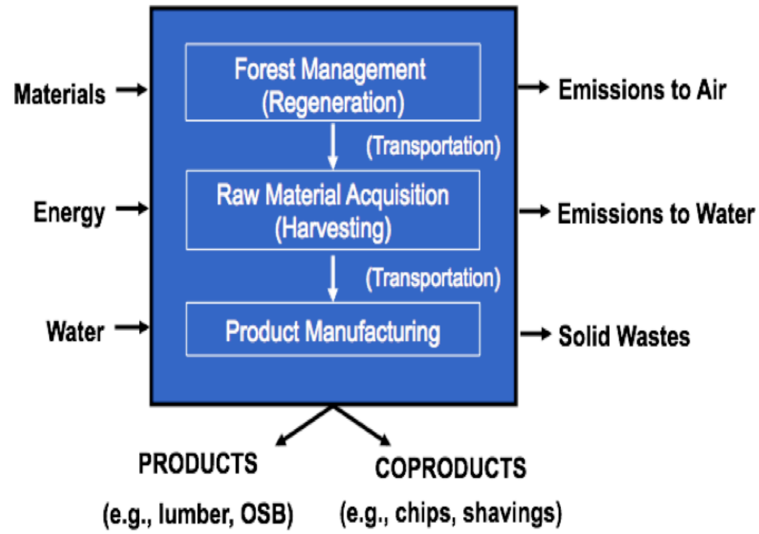

Figure 2. Sawmilling LCI System Boundaries

The input and output data needed for construction of the model are collected for all activities within the system boundary, including from the supply chain (referred to as inputs from the technosphere). Inventory flows can number in the hundreds depending on the system boundary. Flows related to energy, material and water use can be aggregated to generate results for the following impact categories:

- depletion of non-renewable energy resources;
- depletion of non-renewable material resources;
- use of renewable material resources;
- use of renewable primary energy;
- consumption of freshwater.

The word 'depletion' can take on one of two meanings. It can refer simply to the use of energy or material resources, or it can refer to use relative to a measure of reserves. Reserves may in turn be estimated on the basis of known estimated total resources or economically recoverable resources. Both of these approaches are subject to considerable uncertainty and the more straightforward measure of use is therefore generally preferred.

For product LCAs at either the generic (i.e., representative industry averages) or brand-specific level, inventory data is typically collected through survey questionnaires. At an industry level, care has to be taken to ensure that questionnaires are completed by a representative sample of producers, leaning toward neither the best nor the worst, and fully representing any regional differences due to energy use, material sourcing or other factors. The questionnaires cover the full range of inputs and outputs, typically aiming to account for 99% of the mass of a product, 99% of the energy use in its production and any environmentally sensitive flows, even if they fall within the 1% level of inputs. Information obtained through questionnaires is then evaluated using mass balance techniques to ensure completeness and accuracy of data obtained.

Life Cycle Impact Assessment

Life Cycle Impact Assessment (LCIA) follows inventory analysis. This phase of LCA is aimed at evaluating the significance of potential environmental impacts by translating the extensive LCI flows into meaningful environmental measures. Classical Life Cycle Impact Assessment (LCIA) consists of the following mandatory elements:

- selection of impact categories, category indicators, and characterization models;
- the classification stage, where the inventory parameters are sorted and assigned to specific impact categories; and
- impact measurement, where the categorized LCI flows are characterized, using one of several possible LCIA methodologies, into common equivalence units that are then summed to provide an overall impact category total.

The impact measures can be subdivided into mid-point measures that are basically measures of loading on the environment, and end-point measures that are measures of ultimate effects on ecosystem and human health. As might be expected, uncertainty increases as one moves from mid-point to end-point measures, and mid-point measures of loading are therefore generally preferred.

Following are the mid-point LCIA measures cited in ISO 21930:2007[2] and referred to as environmental impacts expressed in terms of the impact categories of LCIA.

- climate change (greenhouse gases);
- depletion of the stratospheric ozone layer;
- acidification of land and water sources;
- eutrophication; and
- formation of tropospheric ozone (photochemical oxidants).

The word 'potential' is used in the more formal terminology for these measures (e.g., global warming potential) to make it clear that while the measures can be linked to end points they are not estimates of the actual end-point effects.

In many LCAs, characterization concludes the LCIA analysis; this is also the last compulsory stage according to ISO 14044:2006. However, in addition to the above mandatory LCIA steps, other optional elements – normalization, grouping, and weighting – may be conducted depending on the goal and scope of the LCA study.

It should be noted that ISO 14044:2006 generally advises against weighting, stating that "weighting, shall not be used in LCA studies intended to be used in comparative assertions intended to be disclosed to the public". This advice is sometimes ignored, resulting in comparisons that can reflect a high degree of subjectivity as a result of weighting.

[2] ISO 21930:2007 Sustainability in building construction — Environmental declaration of building products

Interpretation
The results from the inventory analysis and impact assessment are summarized during the interpretation phase. The outcome of the interpretation phase is a set of study conclusions and recommendations. According to ISO 14040:2006, the interpretation should include:

- identification of significant issues based on the results of the LCI and LCIA phases of LCA;
- evaluation of the study considering completeness, sensitivity and consistency checks; and
- statement of conclusions, limitations and recommendations.

The iterative nature of LCA illustrated by the back-and-forth arrows in Figure 1 means that information gathered in a later stage can highlight effects in a former stage that may require further analysis. When this occurs, the former stage and the following stages have to be reworked taking into account the new information.

LCA Tools
There are two categories of LCA tools: those that are intended for use by LCA practitioners, and those designed for use by engineers, architects or others who want LCA answers without having to go through the full LCA process. Tools intended for practitioners, such as GaBi and SimaPro, come loaded with data options from which the user can select, but allow for the input of new data. The user basically constructs the product or system of interest in the software, links data to the various unit processes, selects measures and prompts the software to generate relevant reports. It is therefore important that the user understand LCA and what is, or is not, acceptable in terms of the standards.

Tools intended for use by non-practitioners, such as the ATHENA Impact Estimator for Buildings, typically have the relevant data sets and measures in the background. The user selects the products or systems of interest and the tools then consulate the encompassed datasets to generate the impact measures without requiring the user to make data or measurement system selections that require a more detailed knowledge of LCA.

A Brief History
Before leaving this overview of LCA it's important to have a sense of the history of this methodology. With its rise in prominence over the last decade or so, newcomers to the subject see it as a relatively new, evolving method and it is too often criticized from that perspective. It is certainly evolving, as is energy simulation and virtually all science-based approaches to sustainability. But the reality is that LCA has been evolving for almost half a century, with early forerunners of LCA, called Resource and Environmental Profile Analyses (REPAs), introduced in the 1960s and applied by major organizations such as Coca Cola Company and Mobil Corporation.

Modern LCA methodology is rooted in the development of standards throughout the 1990s. In 1991, the Society of Environmental Toxicology and Chemistry (SETAC) published "A Technical Framework for Life Cycle Assessments," the first attempt at an international LCA standard. It explicitly outlined the components of contemporary LCA and extended LCA beyond the mere quantification of material and energy flows, thereby paving the way for the use of LCA as a comprehensive decision support tool. Similar developments took place in Northern Europe, with detailed LCA protocols specified in 1995 in the "Nordic Guidelines on Life Cycle Assessments" (Nordic Council of Ministers, 1995). In Canada, the Canadian Standards Association (CSA) released a detailed guideline for conducting LCA in 1994 (Z760). The ISO 14040 series on LCA, released in the late 1990s as an integral part of the ISO 14000 environmental management series of standards, bore a strong resemblance to the original SETAC framework. However, because of ISO's dominant position in the development of international standards, the ISO 14040 series superseded the SETAC guidelines among LCA practitioners. The new ISO 14040:2006 and ISO 14044:2006 standards replaced the original 14040 series.

The other significant development was the launch in 2002 of the Life Cycle Initiative as a combined effort of the United Nations Environment Programme (UNEP) and SETAC. The objectives of the Initiative are to:

- enhance the global consensus and relevance of existing and emerging life cycle approaches methodology;
- facilitate the use of life cycle approaches worldwide by encouraging life cycle thinking in decision-making in business, government and the general public about natural resources, materials and products targeted at consumption clusters;
- expand capability worldwide to apply and improve life cycle approaches; and
- provide global guidance on the establishment and maintenance of LCA databases as the basis for improved inter-linkages of databases worldwide.

The Economic and Social Aspects of Sustainability

Economic

Life cycle cost analysis (LCCA) can be defined as a method for evaluating the total monetary costs associated with a product, project or even a policy over a defined life span or period of time. In the case of a building or infrastructure project, LCCA will typically take account of initial material and construction costs, ongoing routine maintenance and replacement of components, major rehabilitation, and perhaps ultimate demolition and disposal. Future dollar flows are discounted to calculate a present value, which makes it easier to compare one project alternative to another from a cost perspective. Depending on the situation, LCCA can also take account of revenue flows to calculate a net present value and estimated return on investment.

LCA and LCCA are too often confused because of the similarity of terminology and acronyms, with people asking for, or expecting, one type of answer and getting another. The fact is that they are very complementary tools that can be used to compare the life cycle monetary costs associated with environmental improvements.

BEES (Building for Environmental and Economic Sustainability) is an excellent example of a tool developed to bring the environmental and economic considerations into the same decision framework. Developed by the U.S. National Institute of Standards and Technology (NIST), BEES is offered online free of charge at http://www.nist.gov/el/economics/BEESSoftware.cfm. The software currently contains both LCA and LCCA results for 230 building products, which allows the user to compare the environmental and economic implications of product choices.

To make the comparison, however, a weighting system has to be used to combine disparate environmental measures into one score that can be charted against cost. This reflects the fact that, while LCCA only deals with one unit of measure – money, LCA deals with a wide range of flows from and to nature measured in physical units that vary depending on the specific flows and related impact measures. BEES normalizes the various measures to estimate a product's percentage share of the annual per capita impact for each measure. Users can then accept weighting alternatives built into the tool or input their own so that the software can generate an environmental performance score that can be compared to the economic performance score. It is also possible for the user to then weight the two scores relative to each other and combine them into an overall score for a given product.

Another way in which environmental results may be brought into the economic sphere is through externality costing, which refers to the assignment of monetary costs to effects or impacts such as global warming or ozone depletion (i.e., environmental costs borne by society). The environmental impacts estimated in physical units are then converted to dollars, making it possible to aggregate and get a total dollar cost of the environmental impacts. When these externality cost estimates are combined with the internal costs of producing a product, the result is what is referred to as Total Cost Accounting (TCA).

TCA is an area of analysis that has been researched for years and is now having more practical application, although with high levels of subjectivity. There is more certainty if a market system exists, as is the case in some jurisdictions for carbon releases. Otherwise, estimates have to be made, which is why there can be a high level of subjectivity in the process.

Social

Social Life Cycle Assessment (S–LCA) is a subject that has been given a lot of international attention and gained considerable traction over the last few years. There are not yet any standards for S–LCA under ISO. However, a key document titled Guidelines for Social Life Cycle Assessment of Products was released in 2009 under the auspices of the UNEP/ SETAC Life Cycle Initiative. http://www.unep.fr/scp/publications/details.asp?id=DTI/1164/PA

As defined in the UNEP/SETAC publication:

> "A social and socio-economic Life Cycle Assessment (S-LCA) is a social impact (and potential impact) assessment technique that aims to assess the social and socio-economic aspects of products and their potential positive and negative impacts along their life cycle encompassing extraction and processing of raw materials; manufacturing; distribution; use; re-use; maintenance; recycling; and final disposal. S-LCA complements E-LCA with social and socio-economic aspects. It can either be applied on its own or in combination with E-LCA." (p. 37)[3]

The S-LCA Guidelines basically follow the ISO14040 and 14044 standards for LCA, including goal and scope, data collection (inventory), impact assessment and interpretation steps, noting for example that there should be consistency in system boundaries when S-LCA is used alongside environmental LCA. But the guidelines are characterized in the document as a "skeleton", providing guidance for each of the above steps. It suggests that social impacts be classified by stakeholder categories and impact categories, with potential impacts including:

- Human rights;
- Working conditions;
- Health and safety;
- Cultural heritage;
- Governance; and
- Socio-economic repercussions.

A key point highlighted in the Executive Summary of the UNEP/SETAC document is that the guidelines help "… to prevent the use of the technique for applications that would not be appropriate considering its current state of development such as comparative assertions communicated to the public."

[3] The acronym E-LCA is introduced in the UNEP/SETAC document to distinguish environmental LCA from social LCA, but the acronym is not yet widely adopted.

A Cautionary Word About Acronyms

It is important to end this article with a comment about the often-confusing world of acronyms. It was mentioned earlier that life cycle assessment and life cycle costing are frequently confused when the acronyms LCA and LCCA are not used with care. In the section above, the acronym E-LCA was used in the UNEP/SETAC report to distinguish between the environmental and social assessment, S-LCA; a very useful distinction that hasn't yet really caught on. But these potentially confusing situations pale in comparison to the use of LCA to mean 'life cycle approaches'. That use of LCA has occurred more than once in meetings and written material, with the result that people misunderstand what another is saying. Being among those who don't really speak acronym very well, we can only urge extreme care.

Conclusion

It is imperative that decisions that affect the sustainability of our natural resources be backed by good science. For over half a century Life Cycle Assessment has been a key tool in understanding the relative impacts on the environment of our material choices. Over that time it has grown, expanded and improved in many ways. Today LCA is widely accepted as one of the best ways, in fact the premier approach, to compare the environmental impacts of materials, components and services. However, it is still only one tool in the toolbox and it does not deal with all situations or environmental concerns. It is critically important to understand both the strengths and the weaknesses of the tools we use to solve our problems. We are reminded of the old adage "if all you have is a hammer, every problem looks like a nail." But we know that they aren't all nails and it is therefore critically important to bring the whole toolbox – including the hammer – when addressing material choices.

Resources

BEES (Building for Environmental and Economic Sustainability) developed by the U.S. National Institute of Standards and Technology (NIST)
http://www.nist.gov/el/economics/BEESSoftware.cfm.

UNEP/ SETAC Life Cycle Initiative.
http://www.unep.fr/scp/publications/details.asp?id=DTI/1164/PA

Previous Reports from Dovetail Partners addressing LCA and Responsible Materials
http://www.dovetailinc.org/content/dovetail-reports-responsible-materials

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