4.3: Life Cycle Analysis

As environmental awareness becomes more prevalent, businesses are assessing how their activities affect the environment. The environmental performance of products and processes has become a key issue, which is why some companies are investigating ways to minimize effects on the environment. **Life cycle analysis (LCA, sometimes referred to as life cycle assessment)** measures the environmental impact of specific products or processes from cradle to grave. Cradle to grave begins with the gathering of raw materials from the earth to create the product and ends at the point of materials disposal, recycle, or reuse (although LCA uses the term cradle to grave, recycle and reuse scenarios can be built into the analysis for a more accurate cradle to cradle analysis). LCA provides a snapshot in time of a specific product from a specific manufacturer, and it may be difficult to generalize findings. However, LCA is a useful tool for making product and process decisions that consider environmental criteria. The benefit of LCA is that businesses can identify the most effective improvements to reduce cumulative environmental impacts resulting from all stages in the product life cycle, often including upstream and downstream impacts not considered in more traditional analyses (e.g., raw material extraction, material transportation, ultimate product disposal, etc.). LCA is widely used for different purposes by different groups: environmental groups use it to inform consumers on what to buy, legislators use it for creating rules and regulations, and manufacturers use it as they seek to improve design and production standards. Less commonly used methods for environmental comparisons include value–impact assessments, environmental option assessments, and impact analysis matrices.

The LCA process is a systematic phased set of stages and is comprised of four components: goal definition and scoping, inventory analysis, impact assessment, and interpretation. The first stage is goal definition and scoping, which identifies the purpose of the analysis and the context in which the assessment will be conducted. In defining the scope of the LCA, it is important to define the system boundaries. The system boundaries can affect the outcomes of an LCA. Therefore, when comparing multiple products, such as plastic versus corn-based disposable cutlery, it is essential to ensure that the same system boundaries are used to examine both. A functional unit needs to be selected, such as a box of cereal, or a bar of soap, or a ton of grain. The definition of the boundaries should include where the material is extracted (the cradle) and what is the final disposal point for the product (the grave).

The next stage is the inventory analysis where data is collected related to energy, water, and materials usage. LCA includes an analysis of what has been used from the environment, such as raw materials, and what has been released into the environment, such as GHG emissions, solid waste disposal, and wastewater discharges. When moving to the inventory analysis stage, sustainable companies find it much easier to envision the system boundaries for data collection by developing a model of the life cycle or a flow diagram. A flow diagram is a map depicting inputs and outputs within the system boundaries. The diagram allows the investigator to break down the system into a set of subsystems that represent particular phases of the life cycle and shows linkages across these phases.Bhat (1996). For example, the flow chart may include raw material extraction, raw material processing, transportation, manufacture, production fabrication, filling and packaging, assembly, distribution, use, reuse, maintenance, recycle, and waste disposal. The focus of the inventory analysis is data collection of the raw material and energy consumption and emissions to air, water, and land. Data can be collected from various sources.

Suppliers of materials and energy as well as consultants specializing in sustainability can provide valuable information. Other sources that can provide information are government and industrial databases, government reports, existing LCA reports, and laboratory test data. LCA, though very valuable to sustainable businesses, is complex and labor intensive. Software is available to eliminate the need to conduct complex calculations. A sample of LCA software tools can be found at the following Web site: www.life-cycle.org/?page_id=125.Gloria (2009).

The two final stages, life cycle impact analysis and interpretation, evaluate the effects of resources and emissions identified in the previous stage. The third stage uses the findings of the inventory analysis to conduct an impact analysis that considers the consequential effects on population and ecology. Impact analysis provides quantifiable impact information on such issues as environmental and human health, resource depletion, and social welfare. The steps that have been identified with the impact analysis stage are identifying relevant environment impact categories, for example, global warming or acidification; classification or classifying carbon dioxide in relation to global warming; characterization or modeling the potential impact of carbon dioxide on global warming; describing impacts in ways for comparison; sorting and ranking indicators; weighting the most important impacts; and evaluating the results.Scientific Applications International Corporation (2006). The final stage is to interpret the findings from the previous stages to make informed decisions for products and processes.Scientific Applications International Corporation (2006).

The greatest benefit of an LCA is that is allows scientific comparison of products or processes in order to determine the most environmentally friendly option from cradle to grave. This scientific evidence may or may not support our beliefs about the best choice among options (see Note 5.4 "Test Your Knowledge"). However, the limitations of LCA studies should be understood when interpreting results. LCA studies are a static profile capturing the qualities of a specific product at that moment in time. The studies are constrained by the product (or process) selected, the manufacturer selected, its manufacturing practices, its supply chain practices, and the other boundaries of scope defined at the onset of the study. In addition, there are numerous approaches to the use of LCA, which further restrict comparison of studies. For example, depending on the purpose of the LCA, researchers may opt to use economic input–output LCA, screening LCA, process LCA, hybrid LCA, full-product LCA, financial LCA, life cycle energy analysis, or other specific approaches. As such, there exists much controversy over LCA study results as an indication of eco-friendliness.Narayan and Patel (n.d.). Furthermore, there is criticism that LCA studies only focus on environmental aspects and neglect other aspects of sustainability. While not a perfect method, LCA is the best model that exists for considering the environmental impact of products, processes, and services.

TEST YOUR KNOWLEDGE

Based on the results of life cycle analysis (LCA) studies,* which is the more environmentally friendly choice?

1. **Paper or Styrofoam cup**? LCA research shows production of Styrofoam is less energy and water intensive than paper cups and that production of paper cups creates more greenhouse gas (GHG) emissions.Haag, Maloney, and Ward (2006). The conclusion: Styrofoam is better from an environmental standpoint, but neither is ideal.Haag et al. (2006).
2. **Stainless steel coffee mug or ceramic mug or Styrofoam cup**? LCA research shows a reusable ceramic mug is more environmentally friendly than Styrofoam *as long as it is used at least 46 times* (that's 46 cups of coffee!).Paster (2006). The LCA also shows that a stainless steel mug must be used at least 396 times to be more environmentally friendly than Styrofoam.Paster (2006).
3. **Biodegradable to-go food containers or Styrofoam**? LCA research shows biodegradable bioplastic containers made from corn or other agricultural products create more GHG emissions than Styrofoam.Athena Sustainable Materials Institute (2006).
4. **Bioplastic disposable cutlery or plastic**? LCA research shows that bioplastic products made from corn or other agricultural products (such as PLA or PHA) require more energy and produce more GHG emissions in manufacturing than do petroleum-based plastic cutlery.Gerngross and Slater (2000).
5. **Biodegradable or plastic or paper bags**? LCA research shows that plastic bags produce the least environmental impact in manufacturing, transportation, and recycling.Lilienfeld (2007).

* Since the time of the studies mentioned here, products and processes may have improved, thus impacting the results if another LCA study were to be conducted today. Updated LCA studies are needed.

As an example, an LCA of PLA (a corn-based bioplastic manufactured by Dow Chemicals's NatureWorks, LLC) versus plastic found that the manufacture of plastic was less energy intensive, thus emitting fewer greenhouse gases during the manufacturing process, and that the plastic manufacturing process required less water. Therefore, the conclusion was that plastic was a better choice than PLA from an environmental impact standpoint. However, when the manufacturer of PLA, NatureWorks LLC, began purchasing wind power carbon offsets in 2006, the company's LCA studies suggested that NatureWorks's PLA was now the better choice from an environmental impact standpoint.Vink (2007). Others have disagreed with these results based on the argument that the purchase of wind power carbon offsets, or the investment in another company's wind power project, does not bring the wind power to the NatureWorks manufacturing facility and, as such, does not reduce the intensity of the electricity consumption during the PLA manufacturing process.Athena Institute (2006). As this example demonstrates, LCA studies compare a specific product and determines its impact at that point in time, given the manufacturer, its various processes, and the boundaries defined for the study. This limits generalization of the findings to similar products by other manufacturers.
