## Chapter 2
## Goal Definition and Scoping

### What is Goal Definition and Scoping?

Goal definition and scoping is the phase of the LCA process that defines the purpose and method of including life cycle environmental impacts into the decision-making process. In this phase, the following items must be determined: the type of information that is needed to add value to the decision-making process, how accurate the results must be to add value, and how the results should be interpreted and displayed in order to be meaningful and usable.

### How Does Goal Definition and Scoping Affect the LCA Process?

The LCA process can be used to determine the potential environmental impacts from any product, process, or service. The goal definition and scoping of the LCA project will determine the time and resources needed. The defined goal and scope will guide the entire process to ensure that the most meaningful results are obtained. Every decision made throughout the goal definition and scoping phase impacts either how the study will be conducted, or the relevance of the final results. The following section identifies the decisions that must be made at the beginning of the LCA study and the impact of these decisions on the LCA process.

### Getting Started

The following six basic decisions should be made at the beginning of the LCA process to make effective use of time and resources:

1. Define the Goal(s) of the Project
2. Determine What Type of Information Is Needed to Inform the Decision-Makers
3. Determine the Required Specificity
4. Determine How the Data Should Be Organized and the Results Displayed
5. Define the Scope of the Study
6. Determine the Ground Rules for Performing the Work

Each decision and its associated impact on the LCA process are explained below in further detail.

### Define the Goal(s) of the Project

LCA is a versatile tool for quantifying the overall (cradle-to-grave) environmental impacts from a product, process, or service. The primary goal is to choose the best product, process, or service with the least effect on human health and the environment. Conducting an LCA also can help guide the development of new products, processes, or activities toward a net reduction of resource requirements and emissions. There may also be secondary goals for performing an LCA, which would vary depending on the type of project. The following are examples of possible applications for life-cycle inventories, most of which require some level of impact assessment in addition to the inventory:

- *Support broad environmental assessments* - The results of an LCA are valuable in understanding the relative environmental burdens resulting from evolutionary changes in given processes, products, or packaging over time; in understanding the relative environmental burdens between alternative processes or materials used to make, distribute, or use the same product; and in comparing the environmental aspects of alternative products that serve the same use.

- *Establish baseline information for a process* - A key application of an LCA is to establish a baseline of information on an entire system given current or predicted practices in the manufacture, use, and disposal of the product or category of products. In some cases, it may suffice to establish a baseline for certain processes associated with a product or package. This baseline would consist of the energy and resource requirements and the environmental loadings from the product or process systems that are analyzed. The baseline information is valuable for initiating improvement analysis by applying specific changes to the baseline system.

- *Rank the relative contribution of individual steps or processes* - The LCA results provide detailed data regarding the individual contributions of each step in the system studied to the total system. The data can provide direction to efforts for change by showing which steps require the most energy or other resources, or which steps contribute the most pollutants. This application is especially relevant for internal industry studies to support decisions on pollution prevention, resource conservation, and waste minimization opportunities.

- *Identify data gaps* - The performance of an LCA for a particular system reveals areas in which data for particular processes are lacking or are of uncertain or questionable quality. Inventory followed by impact assessment aids in identifying areas where data augmentation is appropriate for both stages.

- *Support public policy* - For the public policymaker, LCA can help broaden the range of environmental issues considered in developing regulations or setting policies.

- *Support product certification* - Product certifications have tended to focus on relatively few criteria. LCA, only when applied using appropriate impact assessment, can provide information on the individual, simultaneous effects of many product attributes.

- *Provide information and direction to decision-makers* - LCA can be used to inform industry, government, and consumers on the tradeoffs of alternative processes, products, and materials. The data can give industry direction in decisions regarding production materials and processes and create a better informed public regarding environmental issues and consumer choices.

- *Guide product and process development* - LCA can help guide manufacturers in the development of new products, processes, and activities toward a net reduction of resource requirements and emissions.

**Determine What Type of Information Is Needed to Inform the Decision-Makers**
LCA can help answer a number of important questions. Identifying the questions that the decision-makers care about will help define the study parameters. Some examples include:

- What is the impact to particular interested parties and stakeholders?
- Which product or process causes the least environmental impact (quantifiably) overall or in each stage of its life cycle?
- How will changes to the current product/process affect the environmental impacts across all life cycle stages?
- Which technology or process causes the least amount of acid rain, smog formation, or damage to local trees (or any other impact category of concern)?
- How can the process be changed to reduce a specific environmental impact of concern (e.g., global warming)?

Once the appropriate questions are identified, it is important to determine the types of information needed to answer the questions.

**Attributional LCA versus Consequential LCA**

During a workshop held in 2003, specifically on life cycle inventory for electricity generation, participants recognized the need to choose an allocation method depending considerably upon whether the life cycle assessment is being performed from an *attributional* or a *consequential* point of view. The term "attributional life cycle assessment" was defined as an attempt to answer "how are things (i.e. pollutants, resources, and exchanges among processes) flowing within the chosen temporal window?" while "consequential life cycle assessment" attempts to answer "how will flows beyond the immediate system change in response to decisions?" For example, an attributional LCA would examine the consequences of using green power compared to conventional sources. A consequential LCA would consider the consequences of this choice in that only a certain amount of green power may be available to customers, causing some customers to buy conventional energy once the supply of greener sources was gone. The choice between conducting an attributional or a consequential assessment depends on the stated goal of the study (Curran, Mann, & Norris 2005).

**Determine the Required Specificity**

At the outset of every study, the level of specificity must be decided. In some cases, this level will be obvious from the application or intended use of the information. In other instances, there may be several options to choose from, ranging from a completely generic study to one that is product-specific in every detail. Most studies fall somewhere in between.

An LCA can be envisioned as a set of linked activities that describe the creation, use, and ultimate disposal of the product or material of interest. At each life cycle stage, the analyst should begin by answering a series of questions: Is the product or system in the life cycle stage specific to one company or manufacturing operation? Or does the product or system represent common products or systems generally found in the marketplace and produced or used by a number of companies?

Such questions help determine whether data collected for the inventory should be specific to one company or manufacturing facility, or whether the data should be more general to represent common industrial practices.

The appropriate response to these questions often rests on whether the life cycle is being performed for internal organizational use or for a more public purpose. Accessibility to product- or facility-specific data may also be a factor. A company may be more interested in examining its own formulation and assembly operations, whereas an industry group or government agency may be more interested in characterizing industry-wide practice. LCAs can have a mix of product-specific and industry-average information. For example, a cereal manufacturer performing an analysis of using recycled paperboard for its cereal boxes might apply the following logic. For operations conducted by the manufacturer, such as box printing, set up, and filling, data specific to the product would be obtained because average data for printing and filling across the cereal industry or for industry in general would not be as useful.

Stepping back one stage to package manufacturing, the cereal manufacturer is again faced with the specificity decision. The data could be product-specific, or generic data for the manufacturing stage could be used. The product-specific approach has these advantages: the aggregated data reflect the operations of the specific paper mills supplying the recycled board, and the energy and resources associated with this stage can be compared with those of similar specificity for the filling, packaging, and distribution stage. A limitation of this option is the additional cost and time associated with collecting product-specific data from the mills and the level of cooperation that needs to be established with the upstream vendors. Long-term confidentiality agreements with vendors may also represent unacceptable burdens compared with the value added by the more specific data.

**Determine the Data Requirements**

The required level of data accuracy for the project depends on the use of the final results and the intended audience (i.e. will the results be used to support decision-making in an internal process or in a public forum?). For example, if the intent is to use the results in a public forum to support product/process selection to a local community or regulator, then estimated data or best engineering judgment for the primary material, energy, and waste streams may not be sufficiently accurate to justify the final conclusions. In contrast, if the intent of performing the LCA is for internal decision-making purposes only, then estimates and best engineering judgment may be applied more frequently. This may reduce the overall cost and time required to perform the LCA, as well as enable completion of the study in the absence of precise, first-hand data.

In addition to the intended audience, the required level of data accuracy could be based on the criticality of the decision to be made and the amount of money involved in the decision.

The alternative decision path, using industrial average data for making recycled paperboard, has a parallel mix of advantages and limitations. Use of average, or generic, data may be advantageous for a manufacturer considering use of recycled board for which no current vendors have been identified. If the quality of these average data can be determined and is acceptable, their use may be preferable. The limitation is that data from this stage may be less comparable to that of more product-specific stages. This limitation is especially important in studies that mix product-specific and more general analyses in the same life-cycle stage. For example, comparing virgin and recycled paperboard using product-specific data for one material and generic data for the other could be problematic.

Another limitation is that the generic data may mask technologies that are more environmentally burdensome. Even with some measure of data variability, a decision to use a particular material made on the basis of generic data may misrepresent true loadings of the actual suppliers. Opportunities to identify specific facilities operating in a more environmentally sound manner are lost. Generic data do not necessarily represent industry-wide practices. The extent of representation depends on the quality and coverage of the available data and is impossible to state as a general rule.

It is recommended that the level of specificity be very clearly defined and communicated so that readers are more able to understand the differences in the final results. Before initiating data collection and periodically throughout the study, the analyst should revisit the specificity decision to determine if the approach selected for each stage remains valid in view of the intended use.

**Foreground and Background Data**

An important element in LCA practice is the distinction that has been made between foreground and background data. The foreground system refers to the system of primary concern. The background system delivers energy and materials to the foreground system as aggregated data sets in which individual plants and operations are not identified. The selection of foreground or background data decides if either marginal or average data are to be used.

**Determine How the Data Should Be Organized and the Results Displayed**
LCA practitioners define how data should be organized in terms of a *functional unit* that appropriately describes the function of the product or process being studied. Careful selection of the functional unit to measure and display the LCA results will improve the accuracy of the study and the usefulness of the results.

When an LCA is used to compare two or more products, the basis of comparison should be equivalent use, i.e., each system should be defined so that an equal amount of product or equivalent service is delivered to the consumer. In the handwashing example, if bar soap were compared to liquid soap, the logical basis for comparison would be an equal number of handwashings. Another example of equivalent use would be in comparing cloth diapers to disposable diapers. One type of diaper may typically be changed more frequently than the other, and market/use studies show that often cloth diapers are doubled, whereas disposables are not. Thus, throughout a day, more cloth diapers will be used. In this case, a logical basis for comparison between the systems would be the total number of diapers used over a set period of time.

Equivalent use for comparative studies can often be based on volume or weight, particularly when the study compares packaging for delivery of a specific product. A beverage container study might consider 1,000 liters of beverage as an equivalent use basis for comparison, because the product may be delivered to the consumer in a variety of different-size containers having different life-cycle characteristics.

**An Example of Selecting a Functional Unit**

An LCA study comparing two types of wall insulation to determine environmental preferability must be evaluated on the same function, the ability to decrease heat flow. Six square feet of four-inch thick insulation Type A is not necessarily the same as six square feet of four-inch thick insulation Type B. Insulation type A may have an R factor equal to ten, whereas insulation type B may have an R factor equal to 20. Therefore, type A and B do not provide the same amount of insulation and cannot be compared on an equal basis. If Type A decreases heat flow by 80 percent, you must determine how thick Type B must be to also decrease heat flow by 80 percent.

**Define the Scope of the Study**
As Chapter 1 explained, an LCA includes all four stages of a product or process life cycle: raw material acquisition, manufacturing, use/reuse/maintenance, and recycle/waste management. These product stages are explained in more detail below. To determine whether one or all of the stages should be included in the scope of the LCA, the following must be assessed: the goal of the study, the required accuracy of the results, and the available time and resources. Exhibit 2-1 provides an example of life cycle stages that could be included in a project related to treatment technologies.

<u>Raw Materials Acquisition</u>
The life cycle of a product begins with the removal of raw materials and energy sources from the earth. For instance, the harvesting of trees or the mining of nonrenewable materials would be considered raw materials acquisition. Transportation of these materials from the point of acquisition to the point of processing is also included in this stage.

Manufacturing
During the manufacturing stage, raw materials are transformed into a product or package. The product or package is then delivered to the consumer. The manufacturing stage consists of three steps: materials manufacture, product fabrication, and filling/packaging/distribution.

*Materials Manufacture* - The materials manufacture step involves the activities that convert raw materials into a form that can be used to fabricate a finished product.

*Product Fabrication* - The product fabrication step takes the manufactured material and processes it into a product that is ready to be filled or packaged.

*Filling/Packaging/Distribution* - This step finalizes the products and prepares them for shipment. It includes all of the manufacturing and transportation activities that are necessary to fill, package, and distribute a finished product. Products are transported either to retail outlets or directly to the consumer. This stage accounts for the environmental effects caused by the mode of transportation, such as trucking and shipping.

Use/Reuse/Maintenance
This stage involves the consumer's actual use, reuse, and maintenance of the product. Once the product is distributed to the consumer, all activities associated with the useful life of the product are included in this stage. This includes energy demands and environmental wastes from both product storage and consumption. The product or material may need to be reconditioned, repaired or serviced so that it will maintain its performance. When the consumer no longer needs the product, the product will be recycled or disposed.

Recycle/Waste Management
The recycle/waste management stage includes the energy requirements and environmental wastes associated with disposition of the product or material.

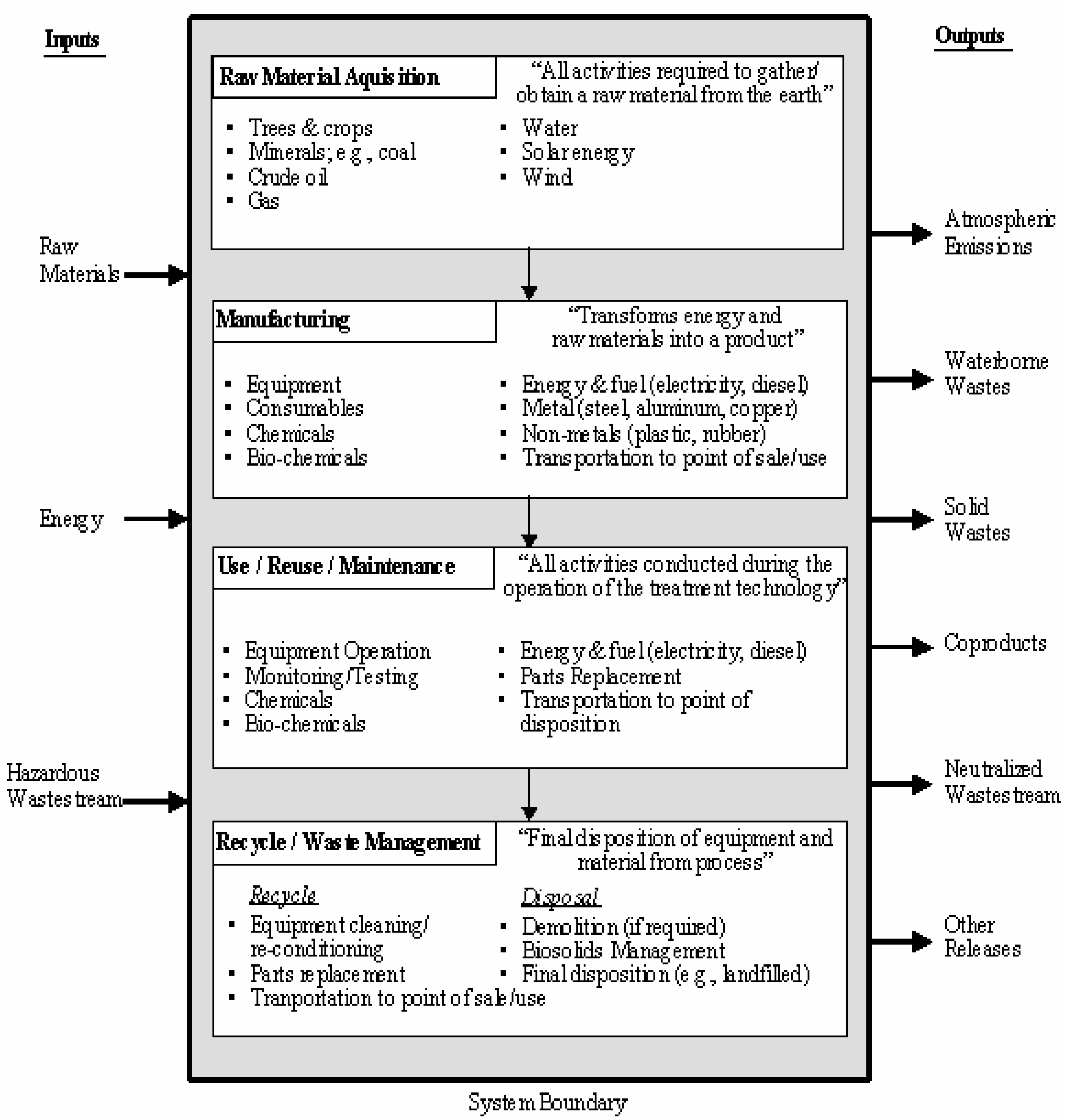



**Exhibit 2-1. Sample Life Cycle Stages for a Treatment Project**

Each step in the life cycle of a product, package, or material can be categorized within one and only one of these life-cycle stages. Each step or process can be viewed as a subsystem of the total product system. Viewing the steps as subsystems facilitates data gathering for the inventory of the system as a whole. The boundaries of subsystems are defined by life-cycle stage categories in Chapter 3. The rest of this chapter deals with defining boundaries of the whole product system. Many decisions must be made in defining the specific boundaries of each system.

Product systems are easier to define if the sequence of operations associated with a product or material is broken down into primary and secondary categories. The primary, or zero-order, sequence of activities directly contributes to making, using, or disposing of the product or material. The secondary category includes auxiliary materials or processes that contribute to making or doing something that in turn is in the primary activity sequence. Several tiers of auxiliary materials or processes may extend further and further from the main sequence. In setting system boundaries, the analyst must decide where the analysis will be limited and be very clear about the reasons for the decision. The following questions are useful in setting and describing specific system boundaries:

- *Does the analysis need to cover the entire life cycle of the product?* A theoretically complete life-cycle system would start with all raw materials and energy sources in the earth and end with all materials back in the earth or at least somewhere in the environment but not part of the system. Any system boundary different from this represents a decision by the analyst to limit it in some way. Understanding the possible consequences of such decisions is important for evaluating tradeoffs between the ability of the resulting inventory to thoroughly address environmental attributes of the product constraints on cost, time, or other factors that may argue in favor of a more limited boundary. Too limited a boundary may exclude consequential activities or elements.

  Depending on the goal of the study, it is possible to exclude certain stages or activities and still address the issues for which the life-cycle assessment is being performed. For example, it may be possible to exclude the acquisition of raw materials without affecting the results. Suppose a company wishes to perform an LCA to evaluate alternative drying systems for formulating a snack food product. If the technologies are indifferent to the feedstock, it is possible to assume the raw materials acquisition stage will be identical for all options. If the decision will be based on selecting a drying system with lower energy use or environmental burdens, it may be acceptable to analyze such a limited system. However, with this system boundary, the degree of absolute differences in the overall system energy or environmental impact cannot be determined. The difference in the product manufacturing stage may represent a minor component of the total system. Therefore, statements about the total system cannot be made.

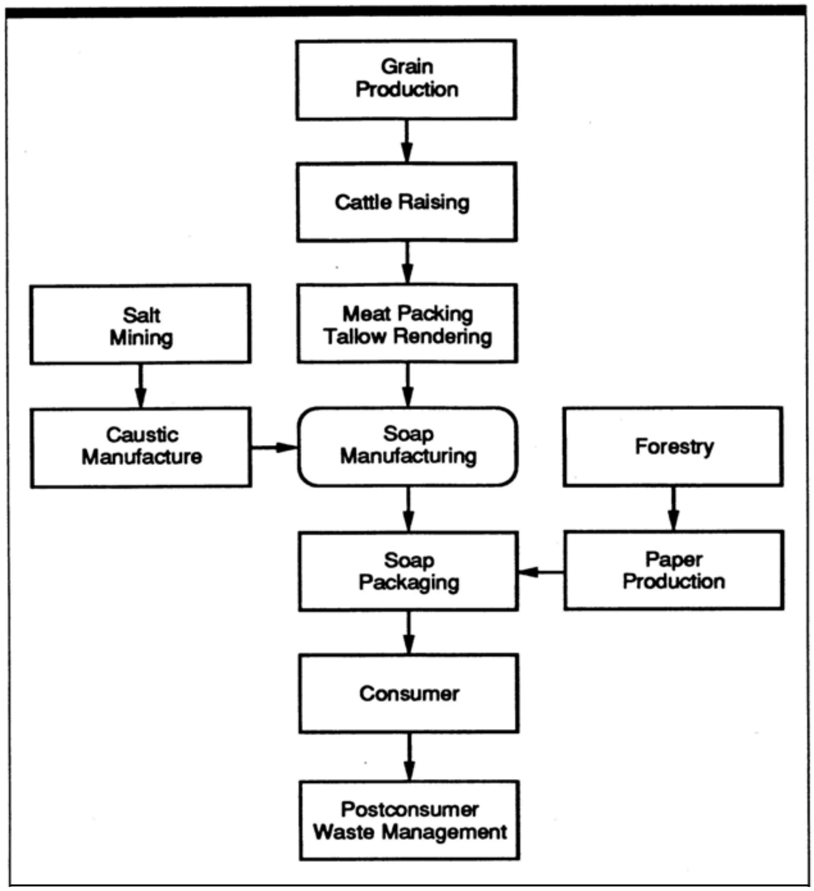
- *What will be the basis of use for the product or material?* Is the study intended to compare different product systems? If the products or processes are used at different rates, packaged in varying quantities, or come in different sizes, how can one accurately compare them? Can equivalent use ratios be developed? Should market shares be considered to estimate proportionate burden form each product in a given category? Is the study intended to compare service systems? Are the service functions clearly defined so that the input and outputs are properly proportioned?

- *What ancillary materials or chemicals are used to make or package the products or run the processes?* Might these ancillary materials or chemicals contribute more than a minor fraction of the energy or emissions of the system to be analyzed? How do they compare by weight with other materials and chemicals in the product systems?

- *In a comparative analysis, are any extra products required to allow one product to deliver equivalent or similar performance to another?* Are any extra materials or services required for one service to be functionally equivalent to another or to a comparable product?

Exhibit 2-2 shows an example of setting system boundaries for a product baseline analysis for a hypothetical bar soap system. Tallow is the major raw material for soap production, and its primary raw material source is the grain fed to cattle. Production of paper for packaging soap is also included. The fate of both the soap and its packaging end the life cycle of this system. Minor inputs could include, for example, the energy required to fabricate the tires on the combine used to plant and harvest the grain.

**Exhibit 2-2. Example Flow Diagram of a Hypothetical Bar Soap System**




In an LCA to create a baseline for future product development or improvement, the unit upon which the analysis is performed can be almost anything that produces internally consistent data. In the bar soap example, one possible usage unit could be a single bar. However, if the product packaging were being analyzed at the same time, it would be important for consistency to consider packaging in different amounts such as single bars, three-packs, and so on.

If the LCA were intended to analyze whether bar soap should be manufactured using an animal-derived or vegetable-derived raw material source, the system boundaries and units of analysis would be more complicated. First, the system flow diagram would have to be expanded to include the growing, harvesting, and processing steps for the alternative feedstock. Then the performance of the finished product would have to be considered. Do the options result in a bar that gets used up at different rates when one material or the other is chosen? If this were the case, a strict comparison of equal-weight bars would not be appropriate.

Suppose an analyst wants to compare bar soap made from tallow with a liquid hand soap made from synthetic ingredients. Because the two products have different raw material sources (cattle and petroleum), the analysis should begin with the raw materials acquisition step. Because the two products are packaged differently and may have different chemical formulas, the materials manufacture and packaging steps would need to be included. Consumer use and waste management options also should be examined because the different formulae could result in varying usage patterns. Thus for this comparative analysis, the analyst would have to inventory the entire life cycle of the two products.

Again, the analyst must determine the basis of comparison between the systems. Because one soap is a solid and the other is a liquid, each with different densities and cleansing abilities per unit amount, it would not make sense to compare them based on equal weights or volumes. The key factor is how much of each is used in one handwashing to provide an equivalent level of function or service. An acceptable basis for comparison might be equal numbers of handwashings. Because these two products may be used at different rates, it would be important to find data that give an equivalent use ratio. For example, a research lab study may show that five cubic millimeters of bar soap and ten cubic millimeters of liquid soap are used per handwashing. If the basis for comparison were chosen at 1,000 handwashings, 5,000 cubic millimeters of bar soap would be compared to 10,000 cubic millimeters of liquid soap. Thus, the equivalent use ratio is 1 to 2.

Because the two soap product types are packaged in different quantities and materials, the analyst would need to include packaging in the system. Contributions of extra ingredients, such as perfumes, might also be considered. The analyst may or may not find that any extra raw materials are used in one or the other. Soaps typically must meet a minimum standard performance level.

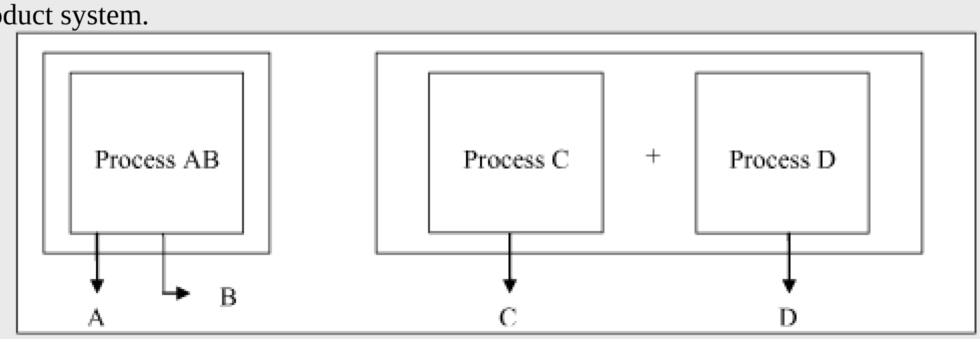
However, if the liquid hand soap also had a skin moisturizer in its formula, the analyst would need to include a moisturizing lotion product in the boundary of the bar soap system on two conditions. The first condition would apply if the environmental issues associated with this component were germane to the purpose of the LCA. The second condition, which is not as clear-cut, is if there is actual value received by the consumer from inclusion of the moisturizer. If market studies indicate that consumers purchase the product in preference to an identical product without a moisturizer, or if they subsequently use a moisturizing lotion after using a non-moisturizing soap, then equivalent use would entail including the separate moisturizing lotion. Including the moisturizing lotion would move the comparison beyond equivalent handwashing to equivalent hand washing and skin moisturizing.

In defining system boundaries, it is important to include every step that could affect the overall interpretation or ability of the analysis to address the issues for which it is being performed. Only in certain well-defined instances can life-cycle elements such as raw materials acquisition or waste management be excluded. In general, only when a step is exactly the same in process, materials, and quantity in all alternatives considered, can that step be excluded from the system. In addition, the framework for the comparison must be recognized as relative because the total system values exclude certain contributions. This rule is especially critical for LCAs used in public forums rather than for internal company decision making. For example, a company comparing alternative processes for producing one petrochemical product may not need to consider the use and disposal of the product if the final composition is identical. The company may also find that each process uses exactly the same materials in the same amounts per unit of product output. Therefore, the company may consider the materials it uses as having no impact in the study results. Another example is a filling operation for bottles. A company interested in using alternative materials for its bottles while maintaining the same size and shape may not need to include filling bottles. However, if the original bottles were compared to boxes of a different size and shape, the filling step would need to be included.

**Applications of System Expansion**

System expansion broadens the system boundaries and introduces a new functional unit to make the two systems being compared equal in scope. Take for example Product A which is produced by Process AB along with co-product B. Product A is to be compared to Product C which is the only product to be produced by Process C. Using system expansion, an alternative way to produce Product B is added to Process C. The comparison is now between Process AB and Process C plus Process D.

Another approach to applying system expansion is by subtracting the environmental burdens of an alternative way of producing Product B (using the same example as before) so that only Product A is compared to Product C. This approach is also referred to as the ***avoided burden*** approach since it is reasoned that the production of any alternative products is no longer needed and the resultant environmental burdens are avoided. The environmental burdens allocated to the product of interest are then calculated as the burdens from the process minus the burdens of an alternative co-product. For example, a process that also generates heat, such as a refrigerator, offsets some of the need for space heating which would be supplied by some other source. The emissions avoided through this reduced demand might include emissions such as carbon dioxide, sulfur dioxide, nitrogen oxide, carbon monoxide and hydrocarbons that are typically emitted from power generation facilities. This process can result in negative accounting of burdens if the subtracted releases do not occur in the main product system.




Resource constraints for the life-cycle inventory may be considerations in defining the system boundaries, but in no case should the scientific basis of the study be compromised. The level of detail required to perform a thorough inventory depends on the size of the system and the purpose of the study. In a large system encompassing several industries, certain details may not be significant contributors given the defined intent of the study. These details may be omitted without affecting the accuracy or application of the results. However, if the study has a very specific focus, such as a manufacturer comparing alternative processes or materials for inks used in packaging, it would be important to include chemicals used in very small amounts.

Additional areas to consider in setting boundaries include the manufacture of capital equipment, energy and emissions associated with personnel requirements, and precombustion impacts for fuel usage. These are discussed later.

After the boundaries of each system have been determined, a system flow diagram, as shown in Exhibit 2-2, can be developed to depict the system and direct efforts to gather data for the life cycle inventory.

Each system step should be represented individually in the diagram, including the production steps for ancillary inputs or outputs such as chemicals and packaging.

**Determine the Ground Rules for Performing the Work**
Prior to moving on to the inventory analysis phase it is important to define some of the logistical procedures for the project.

1. *Documenting Assumptions* - All assumptions or decisions made throughout the entire project must be reported along side the final results of the LCA project. If assumptions are omitted, the final results may be taken out of context or easily misinterpreted. As the LCA process advances from phase to phase, additional assumptions and limitations to the scope may be necessary to accomplish the project with the available resources.

2. *Quality Assurance Procedures* - Quality assurance procedures are important to ensure that the goal and purpose for performing the LCA will be met at the conclusion of the project. The level of quality assurance procedures employed for the project depends on the available time and resources and how the results will be used. If the results are to be used in a public forum, a formal review process is recommended. A formal review process may consist of internal and external review by LCA experts and/or a review by interested parties to better ensure their support of the final results. If the results are to be used for internal decision-making purposes only, then an internal reviewer who is familiar with LCA practices and is not associated with the LCA study may effectively meet the quality assurance goals. It is recommended that a formal statement from the reviewer(s) documenting their assessment of each phase of the LCA process be included with the final report for the project.

3. *Reporting Requirements* - Defining “up front” how the final results should be documented and exactly what should be included in the final report helps to ensure that the final product meets the appropriate expectations. When reporting the final results, or results of a particular LCA phase, it is important to thoroughly describe the methodology used in the analysis. The report should explicitly define the systems analyzed and the boundaries that were set. The basis for comparison among systems and all assumptions made in performing the work should be clearly explained. The presentation of results should be consistent with the purpose of the study. The results should not be oversimplified solely for the purposes of presentation.