Life Cycle Analysis

LCA broadens the environmental discussion by accounting for shifts of environmental problems from one life-cycle stage to another, or one environmental medium (land, air, water) to another. The benefit of the LCA approach is in implementing a trade-off analysis to achieve a genuine reduction in overall environmental impact, rather than a simple shift of impact.

Reference: BEES http://www.bfrl.nist.gov/oae/publications/nistirs/6916.pdf

1) Three main stages in any LCA
   a) **Goal and scope definition**: what materials, processes, products to include; limitations of the study, how broadly will alternatives be interpreted. These issues can be shaped by answering questions like:
      1) Why is the study being conducted?
      2) How will the results be used?
      3) Who will use them?
      4) What level of detail will be needed?
      5) What is the functional unit being analyzed? Select based on the job to be done, not the material used to do the job.

         In the BEES model, the functional unit for most building products is 0.09 m^2 (1 ft^2) of product service for 50 years.[9] For example, the functional unit for the BEES floor covering alternatives is *covering 0.09* m^2 *(1* ft^2*) of floor surface for 50 years*. For two building elements—roof coverings and wall insulation—it was necessary to further specify functional units to account for important factors affecting their influence on building heating and cooling loads (e.g., local climate, fuel type). Otherwise, all product alternatives are assumed to meet minimum technical performance requirements (e.g., acoustic and fire performance). The functional unit provides the critical reference point to which all inventory flows are scaled.

      6) Scoping involves defining the boundaries of the product system under study. The manufacture of any product involves a number of unit processes (e.g., ethylene production for input to the manufacture of the styrene-butadiene bonding agent for stucco walls). Each unit process involves many inventory flows, some of which themselves involve other, subsidiary unit processes. The first product system boundary determines which unit processes are included in the LCA.

         In the BEES system, the boundary-setting rule consists of a set of three decision criteria. For each candidate unit process, mass and energy contributions to the product system are the primary decision criteria. In some cases, cost contribution is used as a third criterion. Together, these criteria provide a robust screening process, as illustrated in Figure 2.1, showing how five ancillary materials (e.g., limestone used in portland cement manufacturing) are selected from a list of nine candidate materials for inclusion in the LCA. A material must have a large contribution to at least one decision criterion to be selected. The weight criterion selects materials A, B, and C; the energy criterion adds material E; and cost flags material I. As a result, the unit processes for producing ancillary materials A, B, C, E, and I are included in the system boundaries.

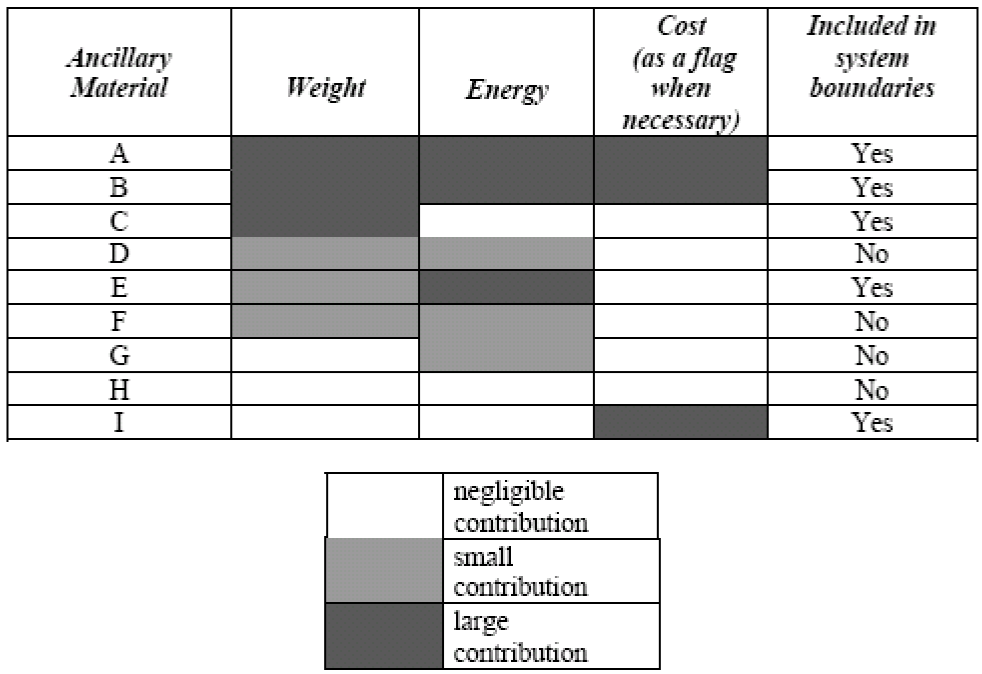

Figure 2.1 Decision Criteria for Setting Product System Boundaries

b) **Inventory analysis**: establish the levels and types of energy and materials input to a system and the product output and environmental releases that result: *materials and energy balances*

1) E.g. materials, material and energy byproducts
2) May also include degree of uncertainty associated with each data item
3) BEES includes inputs of water, energy, and raw materials, and releases to air, land, and water. Data categories are used to group inventory flows in LCAs. For example, in the BEES model, flows such as aldehydes, ammonia, and sulfur oxides are grouped under the air emissions data

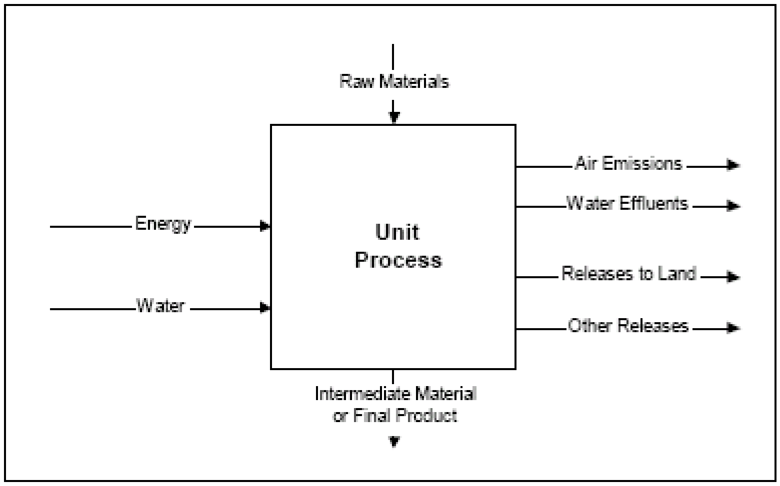

Figure 2.2 BEES Inventory Data Categories

4) Results interpretation

c) **Impact analysis**: What are the outputs of the system to the impacts on the external world, to burdens on external world. Many different "tools" have been developed to make these decisions

1) BEES uses the Environmental Problems approach to impact assessment. This method was developed within the Society for Environmental Toxicology and Chemistry (SETAC) and involves two steps:

 Classification of inventory flows that contribute to specific environmental impacts. For example, greenhouse gases such as carbon dioxide, methane, and nitrous oxide are classified as contributing to global warming.

 Characterization of the potential contribution of each classified inventory flow to the corresponding environmental impact.

2) This results in a set of indices, one for each impact that is obtained by weighting each classified inventory flow by its relative contribution to the impact. For instance, the Global Warming Potential index is derived by expressing each contributing inventory flow in terms of its equivalent amount of carbon dioxide.

3) The Environmental Problems approach does not offer the same degree of relevance for all environmental impacts. For global and regional effects (e.g., global warming and acidification) the method may result in an accurate description of the potential impact. For impacts dependent upon local conditions (e.g., smog, ecological

toxicity, and human health) it may result in an oversimplification of the actual impacts because the indices are not tailored to localities. Another drawback of this method is the unclear environmental importance of the impacts, making the subsequent weighting step difficult.

4) In addition to environmental impacts, other impacts could be assessed, e.g. cost or social impacts.

5) BEES also assesses cost (see web page for details) and combines it with environmental assessments.

6) Normalizing Impacts in BEES

Once impacts have been assessed, the resulting impact category performance measures are expressed in non-matching units. Global warming is expressed in carbon dioxide equivalents, acidification in hydrogen ion equivalents, eutrophication in nitrogen equivalents, placed on the same scale through normalization.

The U.S. EPA Office of Research and Development has recently developed normalization data. These data are used in BEES to place its impact assessment results on the same scale. The data, reported in table 2.11, estimate for each impact its performance at the U.S. level. Specifically, inventory flows contributing to each impact have been quantified and characterized in terms of U.S. flows per year per capita.

Summing all characterized flows for each impact then yields, in effect, impact category performance measures for the United States. As such, they represent a new "U.S. impact yardstick" against which to evaluate the *significance* of product-specific impacts. Normalization is accomplished by dividing BEES product-specific impacts by the fixed U.S.-scale impacts, yielding an impact category performance measure that has been placed in the context of all U.S. activity contributing to that impact. By placing each product-specific impact measure in the context of its associated U.S. impact measure, the measures are all reduced to the same scale, allowing comparison across impacts.

Table 2.11 BEES Normalization Values

Impact	*Normalization Value*
Global Warming	25 582 640.09 g CO_2 equivalents/year/capita
Acidification	7 800 200 000.00 millimoles H+ equivalents/year/capita
Eutrophication	19 214.20 g N equivalents/year/capita
Fossil Fuel Depletion	35 309.00 MJ surplus energy/year/capita
Indoor Air Quality	35 108.09 g TVOCs/year/capita
Habitat Alteration	0.00335 T&E count/acre/capita[a]
Water Intake	529 957.75 liters of water/year/capita
Criteria Air Pollutants	19 200.00 microDALYs/year/capita
Smog	151 500.03 g NO_X equivalents/year/capita
Ecological Toxicity	81 646.72 g 2,4-D equivalents/year/capita
Ozone Depletion	340.19 g CFC-11 equivalents/year/capita
Human Health	158 768 677.00 g C_7H_7 equivalents/year/capita

[a] One acre is equivalent to 0.40 hectares.

Normalized BEES impact scores now have powerful implications. For the first time, the significance of impact scores is evaluated, meaning that scores no longer need be compared to one another without reference to their importance in a larger context. As a result, for example, can competing products contribute even less to that impact. Second, while *selecting* among building products continues to make sense only with reference to the same building element, like floor covering, normalized impact scores can now be compared across building elements if they are first scaled to reflect the product quantities to be used in the building under analysis over the same time period. Take the example of global warming scores for roof coverings and chairs. If these scores are each first multiplied by the quantity of their functional units to be used in a particular building (roof area to be covered and seating requirements, respectively), they may then be compared. Comparing across elements can provide insights into which building elements lead to the larger environmental impacts, and thus warrant the most attention.