TenStep Supplemental Paper

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Lifecycle Inventory

The basis of a Lifecycle Analysis (LCA) study is an inventory of all the inputs and outputs of industrial processes that occur during the lifecycle of a product. These processes include the production, distribution, use and final disposal phases of the product.

Process inputs can be divided into two kinds:

1. Inputs of raw materials and energy resources (environmental input)
2. Inputs of products, semi-finished products or energy, all of which are outputs from other processes (economic input)

Similarly, there are two kinds of output:

1. Outputs of emissions (environmental output)
2. Output of a product, a semi-finished product or energy (economic output)

With information about each process and a process tree of the lifecycle, it is possible to draw up a lifecycle inventory of all the environmental inputs and outputs associated with the product. The result is called the table of impacts. Each impact is expressed as a particular quantity of a substance.

Detailed Inventory process

The inventory process seems simple enough in principle. In practice, it is subject to a number of practical and methodological problems. They are as follows:

- **System boundaries.** In breaking down the lifecycle into processes, it is not always clear how far one should go in including processes that belong to the product concerned.

  For practical reasons a line must be drawn. The production of capital goods, for instance, is usually excluded.

- **Processes that generate more than one product.** An example of this type of process is the electrolysis of salt to produce chlorine. The environmental effects of the electrolysis process cannot be written off entirely as chlorine, as caustic soda and hydrogen are also produced. A suitable allocation rule is needed here; for instance, allocation on a mass basis or economic value of the products.

- **Avoided impacts.** When a disposal process generates a profitable output, such as energy generation at a municipal waste incineration plant, it not only causes impacts but also prevents impacts. This is because it is no longer necessary to produce the energy or the material in a normal way.

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To allow for this, avoided impacts are introduced. These are equivalent to the impacts that would have occurred in actual production of the material or energy. The avoided impacts of a process are deducted from the impacts caused by other processes.

- **Geographical variations.** An electrolysis plant in Sweden uses much less environmentally detrimental electricity than an identical plant in Holland because hydroelectric power is used abundantly in Sweden.
- **Data quality.** Publications on environmental process data are often incomplete or inaccurate. Moreover, the data are subject to obsolescence; there are many cases where processing industries have cut emissions by 90% during the last ten years. The use of obsolete data can therefore cause distortions.
- **Choice of technology.** A distinction can be made between worst, average, and best (or modern) technology. Before starting to collect data, it is important to be aware of the type of technology you are interested in.

Despite these problems, it is often quite feasible to carry out an impact inventory. It is unreasonable, however, to treat the results as an absolute truth. Certain factors, such as the choice of technology and system boundaries, data quality, etc., have to be considered when interpreting them. This is why there always seems to be a disagreement among experts about the environmental soundness of a product.

Impact Assessment

The inventory table is the most objective result of an LCA study. However, a list of substances is difficult to interpret. To make this task easier, lifecycle impact assessment (LCIA) is used to evaluate the impacts.

Two problems exist in impact assessment:

1. Sufficient data isn't available to calculate the damage an impact has on ecosystems.
2. There is sometimes a lack of generally accepted ways of assessing the value of the damage to ecosystems (if this damage can be calculated).

A general approach used through the calculation of environmental effects has three steps:

1. Classification and characterization
2. Normalization
3. Evaluation

The procedure is described here using fictional data.

Classification and characterization

In the classification step, all substances are sorted into classes according to the effect they have on the environment. For example, substances that contribute to the greenhouse effect or that contribute to ozone layer depletion are divided into two classes. Certain substances are included in more than one class.

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Some substances may have a more intense effect than others. This problem is dealt with by applying weighting factors to the different substances. This step is referred to as the characterization step.

The interpretation of these scores may be less confusing than the interpretation of a substance list, but it is by no means without problems. If all the scores for one product are higher than those for another, it is easy enough to conclude which is more environmentally friendly. But if one has a higher score for acidification, while the other has a higher score for the greenhouse effect, justifying such a conclusion becomes more difficult.

Interpretation depends on two factors:

1. **Normalization:** the relative size of the effect compared to the size of the other effects. In this example, it is important to see whether the eco-toxicity score of 100% refers to a very high or an extremely low effect level.
2. **Evaluation:** the relative importance attached to the various environmental effects.

Normalization

For a better understanding of the relative size of an effect, normalization is required. Each effect calculated for the lifecycle of a product is benchmarked against the known total effect for the class. For example, the Eco-indicator method normalizes with effects caused by the average European during a year. Of course, it is possible to choose another basis for normalization.

Normalization enables one to see the relative contribution from the material production to each already existing effect.

Evaluation of the normalized effect scores

Normalization considerably improves our insight into the results. However, no final judgment can be made because not all effects are considered equally important. In the evaluation phase, the normalized effect scores are multiplied by a weighting factor that represents the relative importance of the effect.

Use and Applications of LCA

The main function of LCA is to serve as a decision support tool in business, regulation and policy areas and to structure technology development coherently. Many potential applications are envisaged, such as product improvement and design, environmental management, eco-labeling, green accounting, environmental auditing and reporting, resource management, definition of Best Available Technology (BAT), product policy, strategic industrial planning, strategic environmental policy development, etc. Such a diverse application domain may require an application's specific LCA methodologies or combinations with other decision support tools.

As a general concept, the lifecycle approach aims to support the overall goal of sustainability.

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Tools based on the lifecycle approach usually deal with environmental impact (like resource extraction and emissions) in a non-localized and rather general way, whereas the second group deals with these impacts in a more local and specific way. However, there is a tendency to combine the lifecycle concept with tools for specific processes. For instance, tools such as Environmental Audit (including the EU EMAS program) and Green Accounting are normally in the 'specific process' class.

LCA enables a manufacturer to quantify the amount of energy and raw materials used, and the solid, liquid and gaseous waste generated, at each stage of the product's life. Taking the example of a manufactured product, an LCA involves taking detailed measurements during the manufacture of the product, from the mining of the raw materials used in its production and distribution, through to its use, possible re-use or recycling, and its eventual disposal.

LCA in waste management

LCA has begun to be used to evaluate a city or region's future waste management options. The LCA, or environmental assessment, covers the environmental and resource impacts of alternative disposal processes, as well as other processes that are affected by disposal strategies, e.g. different types of collection schemes for recyclables and changed transport patterns.

Summary

Lifecycle Analysis must be used cautiously, and in the interpretation of the inventory, care must be taken with subjective judgments.

When first conceived, it was predicted that LCA would enable definitive judgments to be made. That misplaced belief has now been discredited. In combination with the trend towards more open disclosure of environmental information by companies, and the desire by consumers to be guided towards the least harmful purchases, LCA is a vital tool.

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