2.2: LCA/LCIA Concepts

Concepts

Goal, Scope, and Definition

Assumptions inherent in an LCA study are apt to change the results and conclusions derived from analysis. In addition, many different types of studies require various levels data collection and analysis. The goal and scope of a LCA defines its intent, targeted audience, and use. The intended use informs further decisions for scope, functional unit of comparison, and data collection. For example, if a LCA study is used internally, a full review panel of LCA experts is not required; however, when providing public environmental claims about a competing product, a review is required.

Inventory analysis

A life cycle inventory (LCI) is the most laborious step of a LCA: data is collected and organized. It often involves contacting companies, accumulating literature sources, and building models using life cycle assessment software. Materials flows, types of materials, product life time, and product energy requirements are collected in the LCI phase.

Life Cycle Impact Assessment

A life cycle impact assessment (LCIA) part of the analysis process collects life cycle inventory data and delivers environmental impacts values. This process greatly reduces the complexity of the data set from hundreds of inputs to 10 or fewer impact categories for decision-making. There are many different methods for LCIA based on location, goals, and scope.

Interpretation

The interpretation step derives from what was found in the other steps for the generation of new information. It is not the last step but iterative. When it is done, the study assumptions, goals, scope, and methods are refined to suit the needs of the study.

Life Cycle Analysis: Goal, Scope and Boundaries

Goal

The first step is defining the goal to give the aim and what it encompasses. There are two types of LCA objectives: (1) descriptive and (2) change-oriented. The descriptive types look at broader aspects of an issues, e.g., how much of the world's carbon dioxide emissions are derived from commuters (light duty vehicles). These broader environmental questions fall within the domain of descriptive LCAs. The second type of LCA is change-oriented, in which two options for fulfilling a function are compared. Typical examples of change-oriented LCAs are paper vs. plastic, flying vs. driving, and gas vs. electric heating. These types of studies can guide the choice of methods to reduce environmental impacts. The intended audience is another part of the goal and scope. The audience may include interest groups such as policy makers, company marketing groups, or product development teams. Additionally, interest groups should be identified. These include companies, funding sources, target audiences, and expert reviewers. It is noted that the intended use of the LCA may be different from the end use because the information may be relevant to other decisions and analyses beyond the original intent.

One specific LCA to compare two products is a "comparative assertion disclosed to the public". In this type of study, "environmental claims regarding the superiority or equivalence of one product vs a competing product which performs the same function" are communicated. These types of studies must follow ISO 14044 standards with the nine steps for a "comparative assertion".

Scope

The scope definition serves the purpose of communicating to the audience what is included and what is excluded. Depending on the goal, there are several types of scopes including cradle-to-gate, cradle-to-grave, and gate-to-gate. There are other words commonly used to describe these scopes:

- **Cradle-to-grave:** includes all flows and impacts from obtaining raw material to disposal and reuse
- **Crade-to-gate:** includes all flows and impacts from raw material to production, but excludes product use and end of life.
- **Gate-to-gate:** only includes flows from production or material processing steps of a product life.

The scope must be carefully selected in consideration of the potential implications not including product stages or phases in the scope of the work. For example, a product may have lower product emissions, but have a shorter lifetime than an alternative

product that would not be communicated in a process stage diagram as seen in Figure 2.2.1. These types of diagrams list the major unit steps considered and clearly show what is not included.

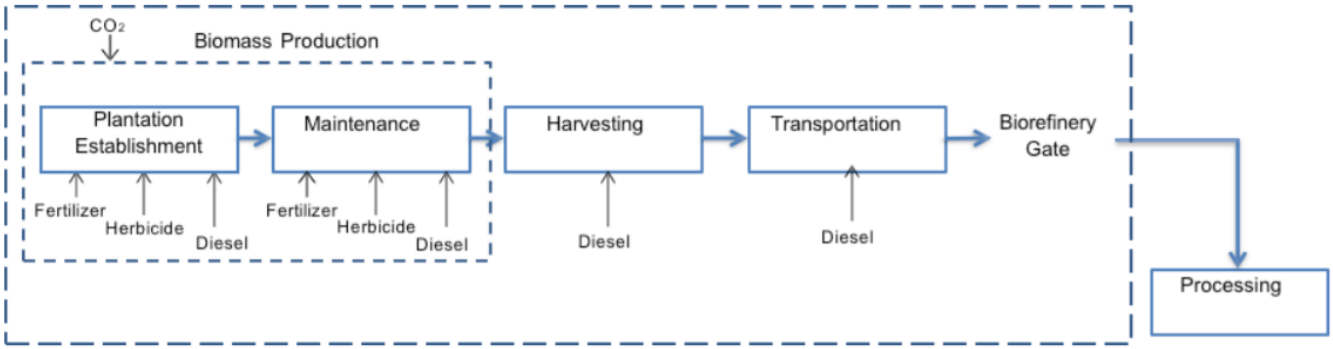

Figure 2.2.1: System boundary diagram of a cradle-to-grave biofuels process.

Temporal boundaries are also established in the scope. Assumptions relating to time can have a large influence on the results. A study timeframe should be picked which will best capture the impacts of the product or processes. A 100-year window is a common temporal boundary, for example, in global warming. In a 100-year temporal window, impacts occurring after 100 years are not part of the overall analysis.

Other aspects to be included in scope are technology and geographical regions. Many studies are spatially dependent so LCA results are not broadly applicable to other regions. Products or services from older technologies often have different impacts than current technologies. Thus, it is important to communicate the type and stage of the technology. In addition, allocation procedure impact assessment methods and should be reported.

Functional Unit

A functional unit is the primary measure of a product or service. ISO states that “the functional unit defines the quantification of the identified functions (performance characteristics) of the product. The primary purpose of a functional unit is to provide a reference to which the inputs and outputs are related. This reference is necessary to ensure comparability of LCA results. The functional unit can be a service, mass of material, or an amount of energy. Selecting appropriate functional units is critical to creating an unbiased analysis. For example, when comparing trains to cars for transportation, the comparison may suffer from the inability to correlate energy inputs and outputs. The real purpose of the train would be to deliver a larger number of people to a specific centralized location. For this example, a better functional unit may be impacts of a train delivering a specific number of people over a specified distance. The results will then be normalized to distance for more reasonable correlations and assessments.

Cut of Criteria

Data collection for an LCA is the most time-intensive and laborious step. Cut-off criteria are used to expedite the process. Cut-off criteria define a level of product content or other parameter to which the study will not consider. One example: materials contents less than 1% of the total product mass are not considered. This allows the LCA practitioner to focus on data from the main flows of the system while systematically eliminating flows which may not influence the results.

Life Cycle Inventory

In addition to data collection, the life cycle inventory (LCI) step is a very laborious aspect of life cycle assessment. The data collected for the product, production process, and product life cycle are used in the impact assessment to determine the environmental impacts. Collecting consistent, transparent, and accurate LCI data is critical to the success of an overall LCA.

Primary and Secondary Data

Example data collected:

- Raw material use
- Energy use
- Transportation distances
- Chemical use
- Waste treatment information
- Process yields
- Life time

- Water use
- Product and co-product flows
- Other flows in or out of the system that are within the defined cut-of-criteria

Tracking the material flows into and out of the defined system is the first step of LCI. After the materials flows have been determined through interviews, literature searches, and measurement, LCA software can be used to track the material process's elementary flows to and from the environment. Elementary flows originate in the environment and are mined or retrieved for use in a process or flows that are released from processes to the environment and are not used by other processes. These elementary flows are the actual materials used and materials released to the environment as a result of the studied product system. In Figure 2.2.2, the two types of LCI data can be seen. On the top half of the figure, process flows such as products, services and other goods are listed. The lower half lists elementary flows such as chemicals released to soil or air.

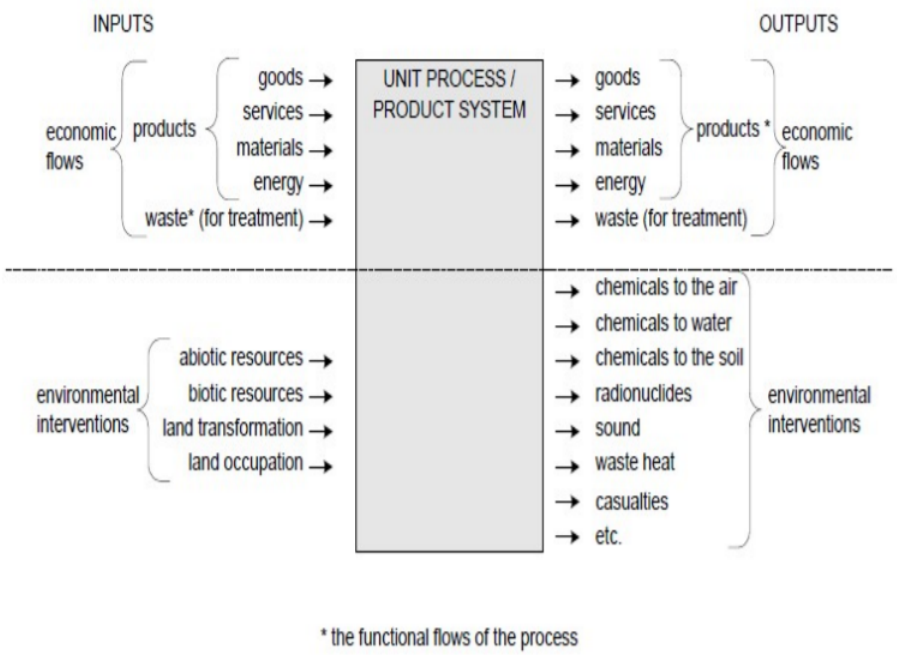

Figure 2.2.2: System boundary diagram of a cradle-to-grave biofuels process.

Life Cycle Impact Assessment

Life cycle impact assessment (LCIA) is among the last steps of LCA. The purpose of a LCIA "is to provide additional information to assess life cycle inventory (LCI) results and help users better understand the environmental significance of natural resource use and environmental releases". The LCIA helps provide significance and results for easier decision making; however, it is important to understand it does not directly measure the impacts of chemical releases to the environment as an environmental risk assessment does. The third step of LCIA follows sequentially after the LCI using the many flows to and from the environment developed in the LCI. These LCI flows, without an impact assessment step, are not easily interpreted and understanding the significance of emissions is impossible. The LCIA is different from a risk assessment measuring absolute values of environmental impacts in that the LCIA helps determine the significance of emissions and impacts in relation to the study scope. The absolute value of the impacts cannot be determined by the LCIA due to (Margni and Curran 2012):

- The relative expression of potential environmental impacts to a reference unit
- The integration of environmental data over space and time
- The inherent uncertainty in modeling environmental impact
- The fat that some possible environmental impact occurs in the future

Even though the LCIA has limitations, it is useful in determining what impacts matter, what unit processes are contributing the most through hot spot analysis and identify best scenario options when environmental tradeoffs occur.

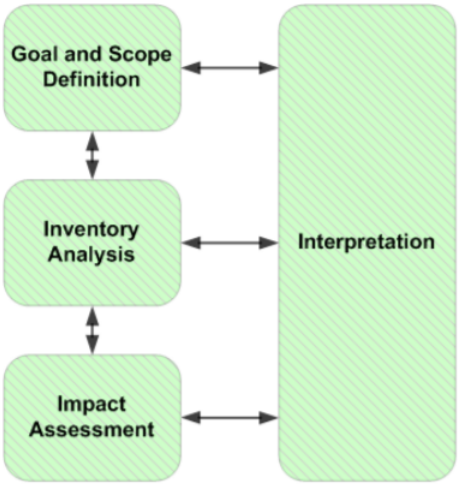

Figure 2.2.3: Life cycle assessment stages. https://commons.wikimedia.org/w/index.php?curid=40862556

According to ISO there are three mandatory processes of a LCIA including Selection of impact categories, Classification, and Characterization, Figure \(\PageIndex{4}\).

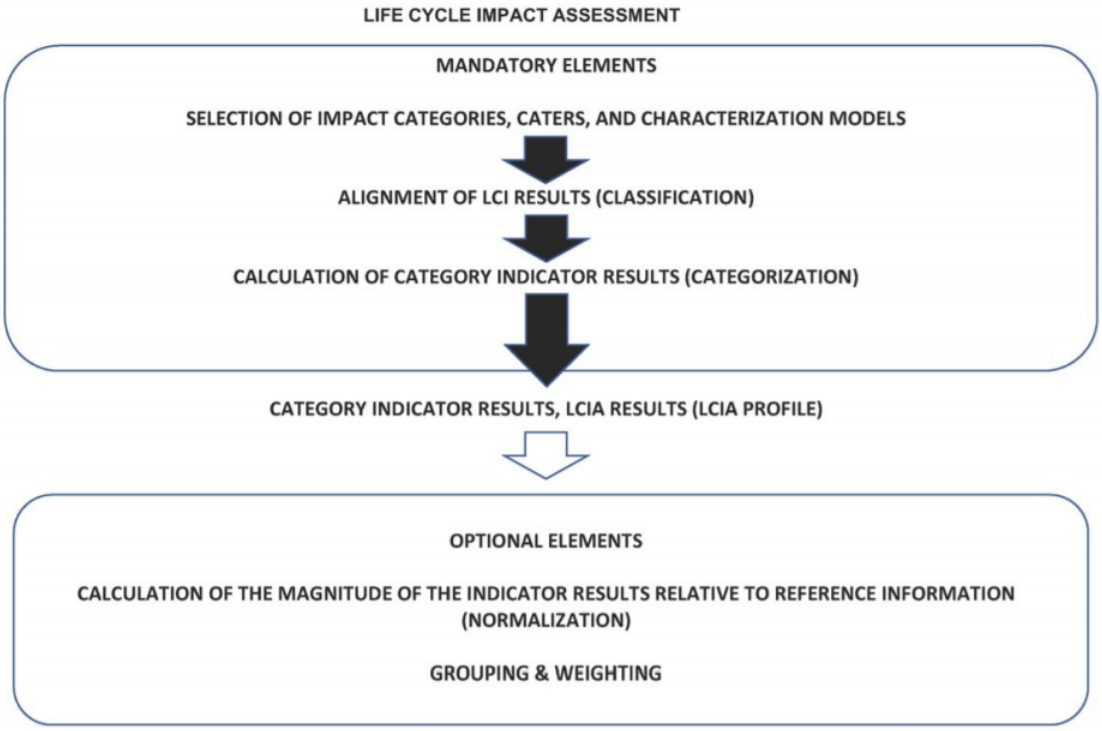

Figure 2.2.4: Impact assessment ISO mandatory and optional steps