Chapter 5
Life Cycle Interpretation

What is Life Cycle Interpretation?

Life cycle interpretation is a systematic technique to identify, quantify, check, and evaluate information from the results of the LCI and the LCIA, and communicate them effectively. Life cycle interpretation is the last phase of the LCA process.

ISO has defined the following two objectives of life cycle interpretation:

1. Analyze results, reach conclusions, explain limitations, and provide recommendations based on the findings of the preceding phases of the LCA, and to report the results of the life cycle interpretation in a transparent manner.
2. Provide a readily understandable, complete, and consistent presentation of the results of an LCA study, in accordance with the goal and scope of the study. (ISO 1998b)

Comparing Alternatives Using Life Cycle Interpretation

Interpreting the results of an LCA is not as simple as two is better then three, therefore Alternative A is the best choice! While conducting the LCI and LCIA it is necessary to make assumptions, engineering estimates, and decisions based on your values and the values of involved stakeholders. Each of these decisions must be included and communicated within the final results to clearly and comprehensively explain conclusions drawn from the data. In some cases, it may not be possible to state that one alternative is better than the others because of the uncertainty in the final results. This does not imply that efforts have been wasted. The LCA process will still provide decision-makers with a better understanding of the environmental and health impacts associated with each alternative, where they occur (locally, regionally, or globally), and the relative magnitude of each type of impact in comparison to each of the proposed alternatives included in the study. This information more fully reveals the pros and cons of each alternative.

Can I Select an Alternative Based Only on the Results of the LCA?

The purpose of conducting an LCA is to better inform decision-makers by providing a particular type of information (often unconsidered), with a life cycle perspective of environmental and human health impacts associated with each product or process. However, LCA does not take into account technical performance, cost, or political and social acceptance. Therefore, it is recommended that LCA be used in conjunction with these other parameters.

Key Steps to Interpreting the Results of the LCA

The guidance provided in this chapter is a summary of the information provided on life cycle interpretation from the ISO standard entitled "*Environmental Management - Life Cycle Assessment - Life Cycle Interpretation*," ISO 14043 (ISO 1998b). Within the ISO standard, the following steps to conducting a life cycle interpretation are identified and discussed:

1. Identification of the Significant Issues Based on the LCI and LCIA.
2. Evaluation which Considers Completeness, Sensitivity, and Consistency Checks.
3. Conclusions, Recommendations, and reporting.

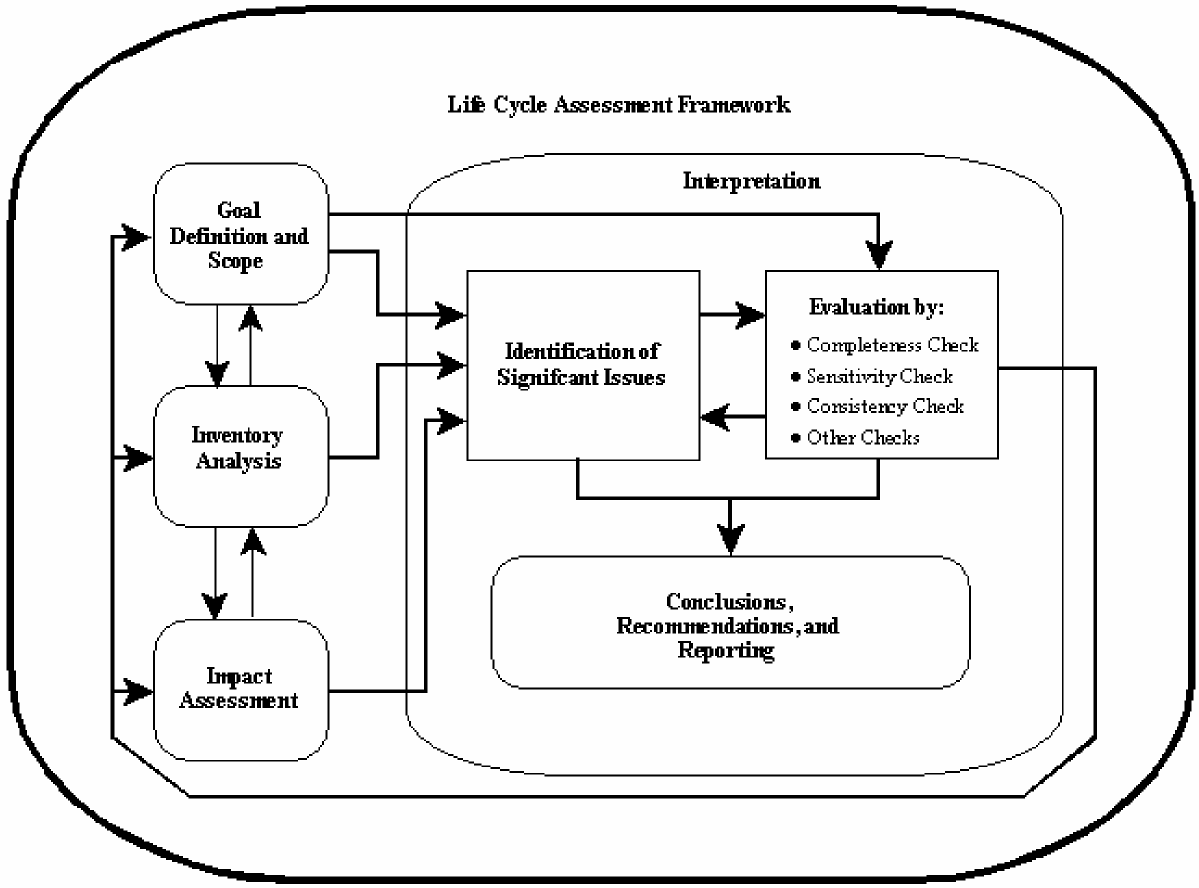

Exhibit 5-1. Relationship of Interpretation Steps with other Phases of LCA (Source: ISO, 1998b)

Exhibit 5-1 illustrates the steps of the life cycle interpretation process in relation to the other phases of the LCA process. Each step is summarized below.

Step 1: Identify Significant Issues

The first step of the life cycle interpretation phase involves reviewing information from the first three phases of the LCA process in order to identify the data elements that contribute most to the results of both the LCI and LCIA for each product, process, or service, otherwise known as "significant issues."

The results of this effort are used to evaluate the completeness, sensitivity, and consistency of the LCA study (Step 2). The identification of significant issues guides the evaluation step. Because of the extensive amount of data collected, it is only feasible within reasonable time and resources to assess the data elements that contribute significantly to the outcome of the results.

Before determining which parts of the LCI and LCIA have the greatest influence on the results for each alternative, the previous phases of the LCA should be reviewed in a comprehensive manner (e.g., study goals, ground rules, impact category weights, results, external involvement, etc.).

Review the information collected and the presentations of results developed to determine if the goal and scope of the LCA study have been met. If they have, the significance of the results can then be determined.

Determining significant issues of a product system may be simple or complex. For assistance in identifying environmental issues and determining their significance, the following approaches are recommended:

- *Contribution Analysis* - the contribution of the life cycle stages or groups of processes are compared to the total result and examined for relevance.
- *Dominance Analysis* - statistical tools or other techniques, such as quantitative or qualitative ranking (e.g., ABC Analysis), are used to identify significant contributions to be examined for relevance.
- *Anomaly Assessment* - based on previous experience, unusual or surprising deviations from expected or normal results are observed and examined for relevance.

Significant issues can include:

- Inventory parameters like energy use, emissions, waste, etc.
- Impact category indicators like resource use, emissions, waste, etc.
- Essential contributions for life cycle stages to LCI or LCIA results such as individual unit processes or groups of processes (e.g., transportation, energy production).

Step 2: Evaluate the Completeness, Sensitivity, and Consistency of the Data

The evaluation step of the interpretation phase establishes the confidence in and reliability of the results of the LCA. This is accomplished by completing the following tasks to ensure that products/processes are fairly compared:

1. Completeness Check - examining the completeness of the study.
2. Sensitivity Check - assessing the sensitivity of the significant data elements that influence the results most greatly.
3. Consistency Check - evaluating the consistency used to set system boundaries, collect data, make assumptions, and allocate data to impact categories for each alternative.

Each technique is summarized below.

Completeness Check - The completeness check ensures that all relevant information and data needed for the interpretation are available and complete. A checklist should be developed to indicate each significant area represented in the results. Data can be organized by life cycle stage, different processes or unit operations, or type of data represented (raw materials, energy, transportation, environmental release to air, land, or water). Using the established checklist, it is possible to verify that the data comprising each area of the results are consistent with the system boundaries (e.g., all life cycle stages are included) and that the data is representative of the specified area (e.g., accounting for 90 percent of all raw materials and environmental releases). The result of this effort will be a checklist indicating that the results for each product/process are complete and reflective of the stated goals and scope of the LCA study. If deficiencies are noted, then a fair comparison cannot be performed and additional efforts are required to fill the gaps. In some cases, data may not be available to fill the data gaps; under these circumstances, it is necessary to report the differences in the data with the final results and estimate the impact to the comparison either quantitatively (percent uncertainty) or qualitatively (Alternative A's reported result may be higher because "X" is not included in its assessment).

Sensitivity Check - The objective of the sensitivity check is to evaluate the reliability of the results by determining whether the uncertainty in the significant issues identified in Step 1 affect the decisionmaker's ability to confidently draw comparative conclusions. A sensitivity check can be performed on the significant issues using the following three common techniques for data quality analysis:

1. Contribution Analysis – Identifies the data that has the greatest contribution on the impact indicator results.

2. Uncertainty Analysis – Describes the variability of the LCIA data to determine the significance of the impact indicator results.

3. Sensitivity Analysis – Measures the extent that changes in the LCI results and characterization models affect the impact indicator results.

Additional guidance on how to conduct a contribution, uncertainty, or sensitivity analysis can be found in the EPA document entitled "Guidelines for Assessing the Quality of Life Cycle Inventory Analysis," April 1995, EPA 530-R-95-010. As part of the LCI and LCIA phases, a sensitivity, uncertainty, and/or contribution analysis may have been conducted. These results can be used as the sensitivity check. As part of the goal, scope, and definition phase of the LCA process, the data quality and accuracy goals were defined. Verify that these goals have been met with the sensitivity check. If deficiencies exist, then the accuracy of the results may not be sufficient to support the decisions to be made and additional efforts are required to improve the accuracy of the LCI data collected and/or impact models used in the LCIA. In some cases, better data or impact models may not be available. Under these circumstances, report the deficiencies for each relevant significant issue and estimate the impact to the comparison either quantitatively or qualitatively.

Consistency Check - The consistency check determines whether the assumptions, methods, and data used throughout the LCA process are consistent with the goal and scope of the study, and for each product/process evaluated. Verifying and documenting that the study was completed as intended at the conclusion increases confidence in the final results.

A formal checklist should be developed to communicate the results of the consistency check. Exhibit 5-2 provides examples of the types of information to be included in the checklist. The goal and scope of the LCA determines which categories should be used.

Depending upon the goal and scope of the LCA, some inconsistency may be acceptable. If any inconsistency is detected, document the role it played in the overall consistency evaluation.

After completing steps 1 and 2, it has been determined that the results of the impact assessment and the underlying inventory data are complete, comparable, and acceptable to draw conclusions and make recommendations. If this is not true, stop! Repeat steps 1 and 2 until the results will be able to support the original goals for performing the LCA.

Exhibit 5-2. Examples of Checklist Categories and Potential Inconsistencies

Category	Example of Inconsistency
Data Source	Alternative A is based on literature and Alternative B is based on measured data.
Data Accuracy	For Alternative A, a detailed process flow diagram is used to develop the LCI data. For Alternative B, limited process information was available and the LCI data developed was for a process that was not described or analyzed in detail.
Data Age	Alternative A uses 1980's era raw materials manufacturing data. Alternative B used a one year-old study.
Technological Representation	Alternative A is bench-scale laboratory model. Alternative B is a full-scale production plant operation.
Temporal Representation	Data for Alternative A describe a recently developed technology. Alternate B describes a technology mix, including recently built and old plants.
Geographical Representation	Data for Alternative A were data from technology employed under European environmental standards. Alternative B uses the data from technology employed under U.S. environmental standards.
System Boundaries, Assumptions, & Models	Alternative A uses a Global Warming Potential model based on 500 year potential. Alternative B uses a Global Warming Potential model based on 100 year potential.

Step 3: Draw Conclusions and Recommendations

The objective of this step is to interpret the results of the life cycle impact assessment (not the LCI) to determine which product/process has the overall least impact to human health and the environment, and/or to one or more specific areas of concern as defined by the goal and scope of the study.

Depending upon the scope of the LCA, the results of the impact assessment will return either a list of un-normalized and un-weighted impact indicators for each impact category for the alternatives, or it will return a single grouped, normalized, and weighted score for each alternative, or something in between, e.g., normalized but not weighted.

In the case where a score is calculated, the recommendation may be to accept the product/process with the lowest score. Or, it could be to investigate the reasons how the process could be modified to lower the score. However, do not forget the underlying assumptions that went into the analysis.

If an LCIA stops at the characterization stage, the LCIA interpretation is less clear-cut. The conclusions and recommendations rest on balancing the potential human health and environmental impacts in the light of study goals and stakeholder concerns.

A few words of caution should be noted. It is important to draw conclusions and provide recommendations based only on the facts. Understanding and communicating the uncertainties and limitations in the results is equally as important as the final recommendations. In some instances, it may not be clear which product or process is better because of the underlying uncertainties and limitations in the methods used to conduct the LCA or the availability of good data, time, or resources. In this situation, the results of the LCA are still valuable. They can be used to help inform decision-makers about the human health and environmental pros and cons, understanding the significant impacts of each, where they are occurring (locally, regionally, or globally), and the relative magnitude of each type of impact in comparison to each of the proposed alternatives included in the study.

Reporting the Results
Now that the LCA has been completed, the materials must be assembled into a comprehensive report documenting the study in a clear and organized manner. This will help communicate the results of the assessment fairly, completely, and accurately to others interested in the results. The report presents the results, data, methods, assumptions, and limitations in sufficient detail to allow the reader to comprehend the complexities and trade-offs inherent in the LCA study.

If the results will be reported to someone who was not involved in the LCA study, i.e., third-party stakeholders, this report will serve as a reference document and should be provided to them to help prevent any misrepresentation of the results.

The reference document should consist of the following elements (ISO 1997):

1. Administrative Information
    a. Name and address of LCA practitioner (who conducted the LCA study)
    b. Date of report
    c. Other contact information or release information
2. Definition of Goal and Scope
3. Life Cycle Inventory Analysis (data collection and calculation procedures)
4. Life Cycle Impact Assessment (methodology and results of the impact assessment that was performed)
5. Life Cycle Interpretation
    a. Results
    b. Assumptions and limitations
    c. Data quality assessment
6. Critical Review (internal and external)
    a. Name and affiliation of reviewers
    b. Critical review reports
    c. Responses to recommendations

Critical Review
The desirability of a peer review process has been a major focus of discussion in many life-cycle analysis forums. The discussion stems from concerns in four areas; lack of understanding regarding the methodology used or the scope of the study, desire to verify data and the analyst's compilations of data, questioning key assumptions and the overall results, and communication of results. For these reasons, it is recommended that a peer review process be established and implemented early in any study that will be used in a public forum.

The following discussion is not intended to be a blueprint of a specific approach. Instead, it is meant to point out issues that the practitioner or sponsor should keep in mind when establishing a peer review procedure. Overall, a peer review process should address the four areas previously identified:

- Scope/boundaries methodology
- Data acquisition/compilation
- Validity of key assumptions and results
- Communication of results.

The peer review panel should participate in all phases of the study: (1) reviewing the purpose, system boundaries, assumptions, and data collection approach; (2) reviewing the compiled data and the associated quality measures; and, (3) reviewing the draft inventory report, including the intended communication strategy.

A spreadsheet, such as the one presented in Appendix A would be useful in addressing many of the issues surrounding scope/boundaries methodology, data/compilation of data, and validity of assumptions and results. Criteria may need to be established for communication of results. These criteria could include showing how changes in key assumptions could affect the study results, and guidance on how to publish and communicate results without disclosing proprietary data.

It is generally believed that the peer review panel should consist of a diverse group of three to five individuals representing various sectors, such as federal, state, and local governments, academia, industry, environmental or consumer groups, and LCA practitioners. Not all sectors need be represented on every panel. The credentials or background of individuals should include a reputation for objectivity, experience with the technical framework or conduct of life-cycle analysis studies, and a willingness to work as part of a team. Issues for which guidelines are still under development include panel selection, number of reviews, using the same reviewers for all life-cycle studies or varying the members between studies, and having the review open to the public prior to its release. The issue of how the reviews should be performed raises a number of questions, such as these: Should a standard spreadsheet be required? Should oral as well as written comments from the reviewers be accepted? How much time should be allotted for review? Who pays for the review process?

The peer review process should be flexible to accommodate variations in the application or scope of life-cycle studies. Peer review should improve the conduct of these studies, increase the understanding of the results, and aid in further identifying and subsequently reducing any environmental consequences of products or materials. EPA supports the use of peer reviews as a mechanism to increase the quality and consistency of life-cycle inventories.

Conclusion

Adding life cycle assessment to the decision-making process provides an understanding of the human health and environmental impacts that traditionally is not considered when selecting a product or process. This valuable information provides a way to account for the full impacts of decisions, especially those that occur outside of the site that are directly influenced by the selection of a product or process.

Remember, LCA is a tool to better inform decision-makers and should be included with other decision criteria, such as cost and performance, to make a well-balanced decision.

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