Guidance for Multi-Stakeholder Life Cycle Scoping, with a Food Container Example

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Executive Summary

Demand for disclosure of the environmental performance of goods and services is rising in the United States and world-wide. This demand is driven by the concerns of the public, the government, non-governmental organizations and retailers (notably Wal-Mart). In response manufacturers produce reports in many non-comparable formats, and this has led to confusion and inefficiency in the market.

The technique of life cycle assessment (LCA) holds out the promise of efficient and effective tools to measure the environmental impacts of products, but the international standards on life cycle assessment were designed for flexibility: they do not provide a rigid guideline for how studies should be performed. As a result outputs from different life cycle studies are often not comparable because the studies have different scopes.

Recognizing that for LCA data to be comparable it would have to share the same scope, the Institute for Environmental Research and Education organized a group of industry representatives to develop a scoping document. The goal was to provide a basis for ongoing and new studies, thus reducing both costs and the variability introduced by different scopes. From the beginning, the group worked under three principles:

1. The scoping should be technically strong;
2. It should provide a level playing field;
3. It should minimize the costs to all participants.

The group used a multi-serving primary food container as an example around which to organize the scoping decisions, and it strictly followed the requirements of the ISO 14040 and ISO 14044 standards in developing the scope. The goal was to provide guidance for LCAs performed in the USA, but comparative assertions were not intended. Although the scoping effort provides a good basis for environmental product declarations, the group did not develop an environmental product declaration.

The US Life Cycle Inventory Database was specified both as a source of background, non study-specific data and as a repository of newly-developed foreground data. Where background data was not available through this resource, it was suggested that it be found in the Ecoinvent data base or in published peer-reviewed studies. Foreground data would be developed through a statistically-valid sampling approach.

The recycling portion of the life cycle was integrated into the life cycle: recycling activities thus become additional unit processes in the product system, and recycled materials become co-raw materials. Waste management was identified as unit processes that are part of the life cycle. This approach is fundamentally one of system boundary expansion, the method that the group selected to address allocation. Where system boundary expansion was not possible, the allocation was to be performed via mass allocation.

The decisions about the impact assessment phase of the LCA were considerably more problematic. The field of life cycle impact assessment is less well-developed than that of life cycle inventory analysis, and the potential impact assessment models available for the USA are typically not validated. As a result, there is lower certainty that the impact indicators correlate well with the actual impacts.

The primary exceptions to this rule are the climate change indicators developed by the Intergovernmental Panel on Climate Change, and the resource depletion indicators. The group selected primarily inventory indicators for resource depletion. The impact is therefore characterized as the use or loss of the resource itself. Although this is not an ideal way to evaluate these impacts, the lack of nationally recognized methods to evaluate such issues as soil loss requires this simplified approach.

The group chose the US EPA TRACI methods for evaluating eutrophication, acidification and photochemical smog. These indicator methods are based on fate and transport models of these pollutants in the United States and portions of Canada. However, decisions about the data collection methodology meant that regionalization was impossible to evaluate. Thus these indicators have less environmental relevance than is possible (and desirable).

The group chose USE-tox as the method of evaluating human and ecotoxicity. Although this method includes persistence, bioaccumulation and toxicity, and is the best available method, it has serious technical problems. The human toxicity indicator is based on the value judgments of the World Health Organization’s technical panel for Disability Adjusted Life Years (DALYs) and is thus an endpoint indicator. Inorganic species (especially metals) are poorly characterized in the USE-tox model, which was developed for organic materials. Users of these results are urged to use caution when evaluating the life cycle toxicity of products.

Life Cycle Assessment is a powerful tool for evaluating the environmental performance of products, but to maximize its utility it is important to look over the entire life cycle of a product system and to normalize the results to the function provided by the product. This study used food packaging as a model to organize the thoughts of the group, but the contents of a package are much more important sources of environmental impacts than the package itself. Looking at packaging in isolation can only draw attention away from the primary sources of environmental degradation.

Although there is still more work to be done in developing impact assessment models, this scoping document provides a framework for LCA scoping in the USA, especially as it relates to packaging. The report provides a simple way for practitioners and commissioners of LCAs to minimize the effort in scoping a study and to maximize the comparability of studies.

Guidance for Multi-Stakeholder Life Cycle Scoping, with a Food Container Example

Background:

Life Cycle Assessment is a tool to measure the environmental sustainability of products and services. It looks holistically over the entire value chain and expresses the environmental results in terms of the useful function provided by the systems being studied. As a result it is a very strong tool for decision-making: technically strong yet easy to understand and use for many different purposes.

LCAs have been used for policy and legislation, and business related purposes including: environmental management systems and environmental annual reports, product stewardship, design for environment, environmental marketing, and for environmentally preferable purchasing.

Almost every kind of product has been evaluated, from paper to airplanes, from cups to government policies. Many of the studies performed provided data to databases in the form of unit process inventories. These unit process data are the building blocks needed to provide background data for life cycle inventories and impact assessment models for any product. However, the strength of LCA is that it covers the entire life cycle of the product system, not only unit processes or "cradle to gate" issues, and not only carbon footprints, but all the environmental issues related to every stage of the life cycle. A full assessment of the entire life cycle, normalized to the product's function is needed to provide the knowledge to achieve better environmental outcomes.

The International Organization for Standardization (ISO) has developed several voluntary standards for performing life cycle assessments. The primary standards are ISO 14040, which covers general requirements and scoping, ISO 14044, which covers the requirements for performing and reporting LCAs, and ISO TR 14025, which covers the use of LCA for creating environmental product declarations. These standards lay out all the decisions that must be made during the scoping phase of a life cycle assessment. This report describes how to meet the requirements of those standards, and illustrates it with an actual multi-stakeholder scoping exercise for a food container.

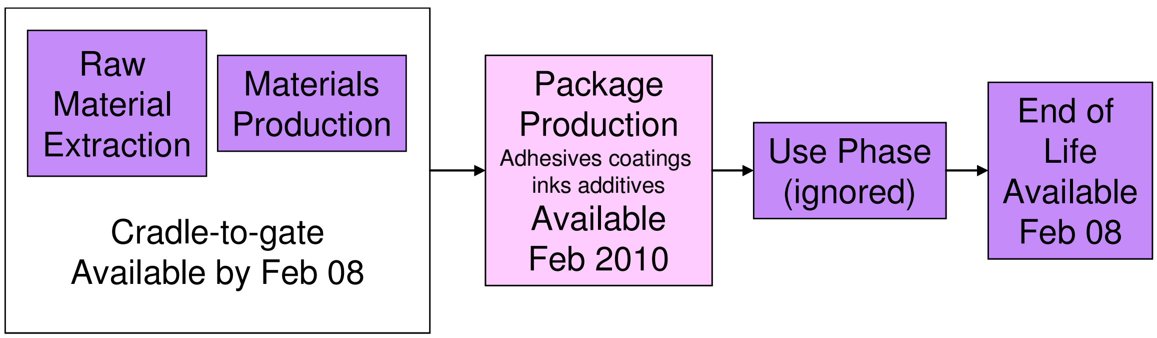
The Wal-Mart LCA Sustainable Package Scorecard effort has had ripples throughout the US economy. It has adopted a life cycle approach to the scorecard. Wal-Mart has required its vendors to provide life cycle assessment inventory data for the major materials used in packaging. End of life data was provided by the US EPA based on its solid waste studies. Wal-Mart's approach to this program is one of continual improvement, and later efforts are intended to cover the entire life cycle.

Furthermore, Wal-Mart has adopted a life cycle approach to its entire sustainability program, using it as a way to achieve its goal of selling only sustainable products.

The interest of vendors and other interested parties in having sound science behind future improvements in the Wal-Mart Packaging Scorecard and its propose product Scorecard was an immediate driver behind the development of this document. However, the results of this multi-stakeholder effort are applicable for any multi-stakeholder LCA scoping process. The principles guiding this effort were threefold:

1. To provide a technically strong and transparent basis for LCAs
2. To provide a level playing field for all players, and
3. To keep the cost of the actual LCA studies as low as practicable while maximizing the utility and quality of the work.

Figure 1 Wal-Mart Packaging LCA Plan



The first rollout of the Wal-Mart data began in the US in February 2008 and as of this writing (August 2008) is still underway. The next phase of the scorecard is intended to include the entire life cycle, filling in the intervening steps, and it will expand to other countries as well.

In order for life cycle data to be appropriate, reproducible and comparable among different products, it is essential that the studies all be performed using the same assumptions, models and boundary conditions. This report describes a scoping project that was performed between December 2007 and July 2008 to serve as an example of a multi-stakeholder open LCA scoping process, and to provide guidance to others seeking to develop a life cycle scoping document for other product categories. The scoping was performed to conform to the requirements of ISO 14040, ISO 14044 and ISO TR 14025. These standards describe the requirements for scoping a LCA study.

The authors of this report represent industries and interested parties who wanted to provide support to the Wal-Mart effort and all similar efforts within industry. No participant committed to undertake the life cycle inventory data collection, (although some did, in fact do so within these scoping guidelines), but they concluded that those wishing to do the work would be best served by following this scoping guidance.

All decisions taken in the scoping effort were determined via consensus. The work included two face-to-face meetings, but most of the work was completed via conference calls.

Because the first users of this guidance will be Wal-Mart and its vendors, we wished to evaluate a packaging application that would include as many stakeholders as possible. Therefore we chose a package category that could be made of as many different materials as possible. A visit to a few Wal-Mart stores showed that primary food packaging was most likely to fill that need. Food packaging is made of glass, aluminum, steel, flexible and rigid plastic and even paper. Representatives of all those industries participated in the process, either as authors of the work or as interested parties reviewing the work.

We have also shared this information and updates of this work with other interested parties, such as the Tag and Label Manufacturers, the Sustainable Packaging Initiative, the Closure Manufacturers Association, the Grocery Manufacturers Association, and the Food Marketing Association.

Process

Participation

This scoping document was developed in an open consensus manner. The initiation of the process was by the Institute for Environmental Research and Education (IERE), but no work began until representatives of the plastics, glass, steel and aluminum industries agreed to participate. Only industry associations, not individual companies, were permitted to participate. However, industry groups were sometimes represented by one of their member companies. The industry representatives could and did change from meeting to meeting depending on the topic being covered and the availability of the representatives. From the beginning, efforts were made to include as many trade organizations as possible. Non Governmental Organizations besides IERE were also invited to participate. Many organizations participated briefly or intermittently. Near the end of the process, two independent LCA experts were brought into the process to act as fresh eyes and to assure that any question of the interpretation of the LCA standards, LCA practice or existing LCA tools was appropriately addressed.

The group met primarily by phone, but two face-to-face meetings were held to discuss issues that required more intensive communication. The minutes of all the meetings are archived on the IERE website.

Decisions

All decisions were made in a consensus manner, through open discussion of the issues. There was a wide range of experience of the industry representatives, and it was agreed that all decisions made by the group would be considered to be straw-man decisions until confirmed by their relevant industry groups. This allowed the representatives with less LCA experience to confer with their colleagues and members.

All the decisions made hinged on three principles:

1. The work should be technically strong. This means that the best available science should be used, and where the level of knowledge is less sure, open issues should be disclosed.
2. The work should represent a level playing field for all participants. No decisions were made with the intent of favoring one material over another. There were very frank and open discussions about this issue early on in the process.
3. The work should be designed to minimize the cost to all participants, both those in the room and those who could make use of the work in the future.

Content of the work

From the beginning of the project, the goal was to provide an ISO-conforming life cycle scoping document. Therefore, the agenda was simple: a full listing of the scoping decisions required by the relevant standards was made, and the group made its way through the list until all questions were discussed and decided upon. That list is available at the back of this document. The remainder of this document goes through these required decisions, discussing the relevant issues surrounding each one, and describes the logic behind the decisions.

The System Function and Functional Unit

Every product provides at least one function: indeed, it is the function that is purchased, and provides social and economic value. There are many different ways to achieve the same function, however. For example, the outside sheath of a building protects the building structure and contents from the weather. One can achieve this function with brick, stucco, stone, glass, wood siding, wood shingles, steel, vinyl siding and other materials. Each of these materials has its own environmental impacts and virtues. The first scoping task is to identify the function of the system being studied.

The function of providing primary containment for food was chosen to illustrate this effort. It was chosen for the very reason that it would bring together many stakeholders, and thus provide an illustration of how to perform multi-stakeholder scoping efforts.

> ***…the environmental impact of producing the food contained in the package was much larger …than the environmental impact of producing the package itself: …Failure of the package incurs all the environmental impact of producing the content, and therefore has more implications than the loss of the package itself.***

Knowing that one is scoping a food container is not enough. One must also choose a functional unit. The functional unit is important because all results will be expressed relative to the functional unit. With some important exceptions (e.g. a kilowatt-hour delivered) a functional unit has three elements: a measure of extent, a measure of quality, and a measure of time. For example, one might choose a functional unit for paint: it covers one square meter (extent) of interior wall (quality) for five years (time). This paint cannot be directly compared to exterior paints, because the quality is different. However, it could be directly compared to wallpaper because the two products have the same quality: they perform the same function. Of course, there are some functional units that are not like that, e.g., a kilowatt-hour delivered.

For this study we chose a functional unit of one retail primary package containing multiple food servings of shelf-stable food for at least a year, with the results to be expressed in units of ounces. The size of the package was not specified, but it was imagined to be about 16 ounces. This functional unit was chosen in part to maintain the participation of the largest number of stakeholders. The period of a year was chosen to represent the annual growing season.

The group recognized that the environmental impact of producing the food contained in the package was much larger (estimated 20 to 50 times larger) than the environmental impact of producing the package itself: therefore, the group recommended that the packaging be examined in the context of its content. Failure of the package incurs all the environmental impact of producing the content, and therefore has more implications than the loss of the package itself.

The Audience and Intended Use.

The primary audiences of this document are Retailers and Consumer Packaged Goods Manufacturers (CPGs). Business to business industries and governmental bodies are secondary intended audiences. A third audience is those producing environmental product declarations and non-governmental organizations.

It is intended to provide guidance on how to perform a life cycle assessment of a package in such a manner that the outcome will be technically rigorous, transparent, cost effective and provide a level playing field.

Although this document describes a scope of an LCA for a food package whose last production step was in the USA and Canada, many of the decisions made will be applicable to the LCA of any product at any national level. The summary scoping table at the end of this documents notes whether each decision is applicable only at the USA & Canada level or at the global level, whether the information is applicable for food packaging or all packaging or all LCAs. Thus the table provides guidance for those wishing to scope another LCA using this guidance, identifying which of the decisions embodied here are applicable to their situation and which are not, the latter requiring different decisions to be made.

This LCA scoping is not intended to support an assertion of the overall environmental superiority of one product over another.

System Boundaries

The group developed a general scoping flow chart for food packaging, as can be seen in Figure 2. Note in this figure that recycling and end of life are treated as separate unit processes within the life cycle. The entire life cycle of the package, including use and disposal are included.

Certain cutoff rules were made, to wit:

1. 99% of all mass should be captured
2. 99% of all energy use should be captured
3. All known toxic issues should be captured

A cutoff rule means that all known inputs to a product system are identified, and life cycle inventories are developed for each input. The cutoff rules allow one to avoid data collection for trivial inputs. These rules provide clear direction for data collection.

Each industry group provided a comparable flow chart that expressed the particular processes of the packaging system they represented. These are shown in Figures 3 to 7.

Figure 2 General System for Food Containers

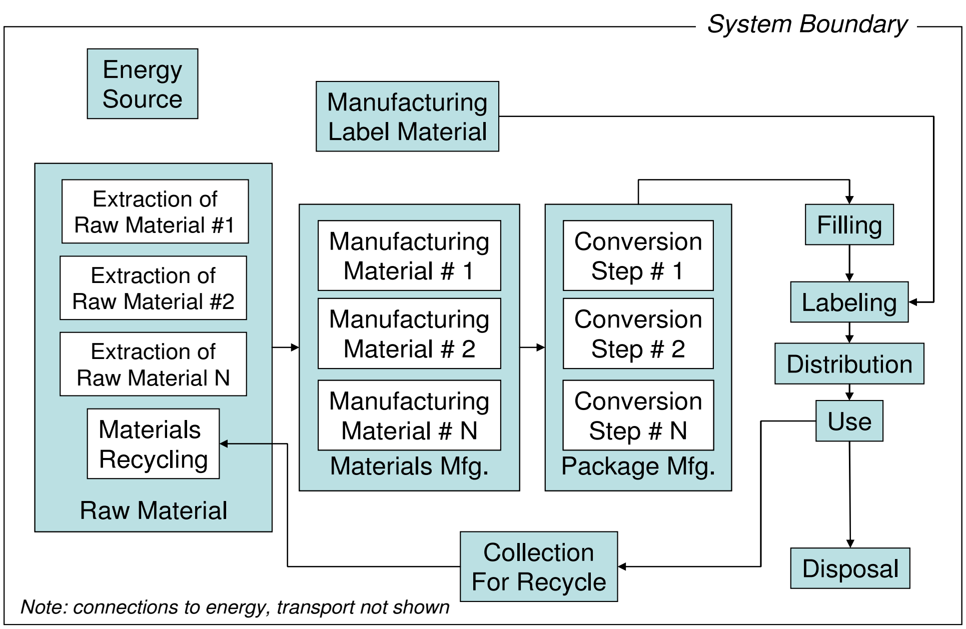


Figure 3 Glass Container System

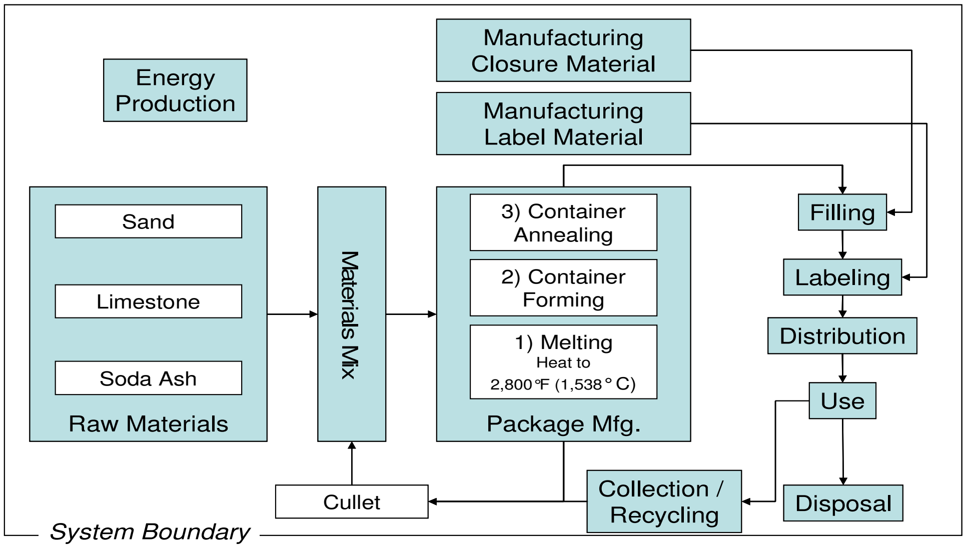


Figure 4 Steel Container System

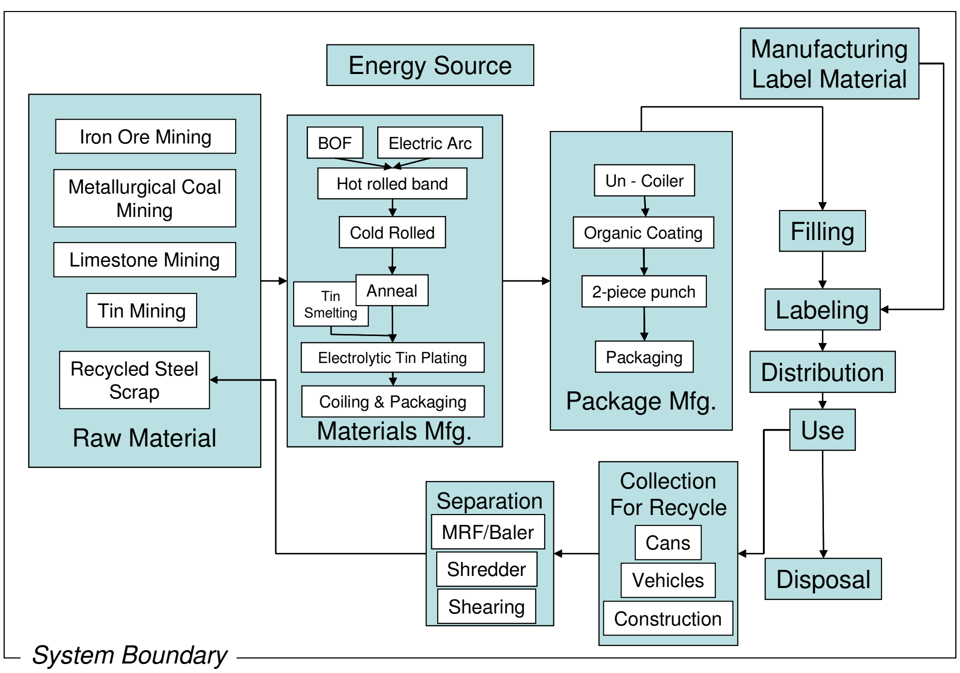


Figure 5 Flexible Container System

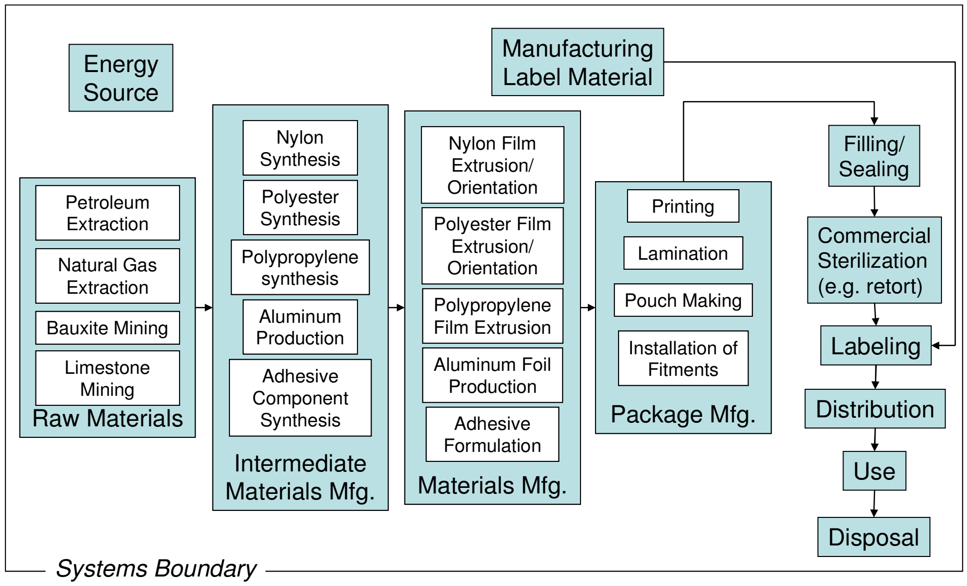


Figure 6 Aluminum Container System

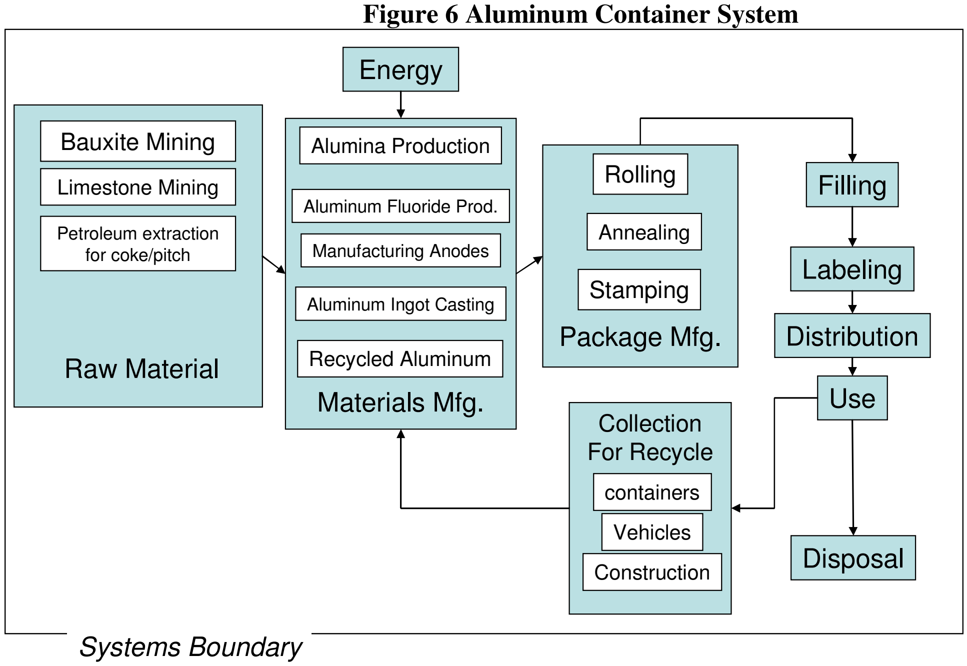


Figure 7 Recycled PET System

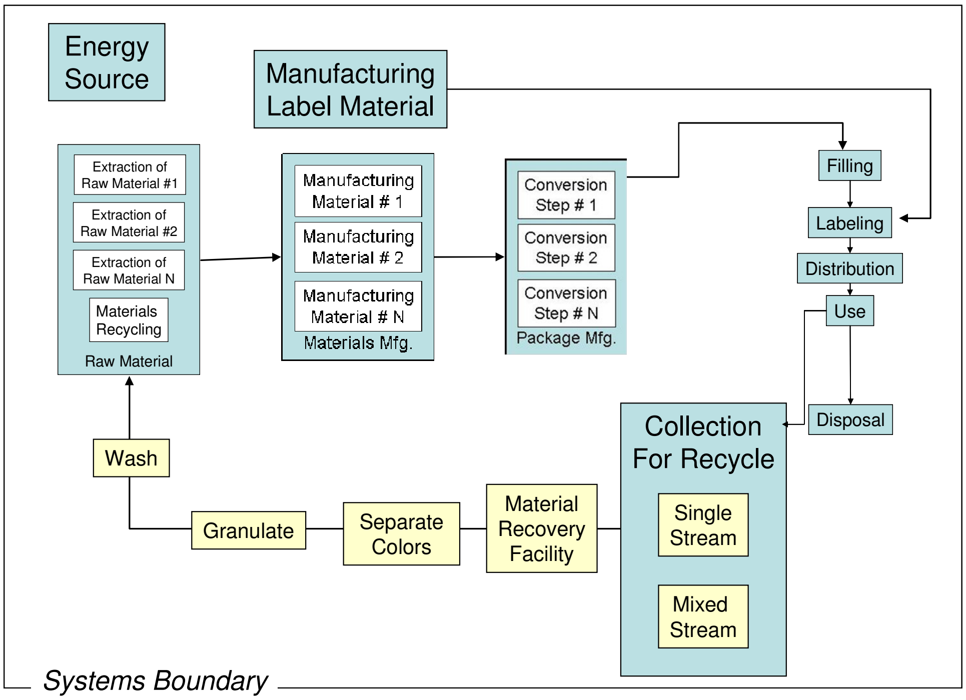


Figure 7 illustrates the integration of recycling into the general LCA system. Although it does not show the entire life cycle of PET containers, it shows how detailed recycling unit processes can be included in the program, permitting an integrated systems view while focusing on different foreground unit processes.

Of course, these are only examples, and for each specific container a unique flow chart should be produced.

The group also chose a geographic system boundary: the systems for study were only those packages whose last processing step before filling was made in the USA or in Canada. It was felt that this geographic scope included reasonably comparable process technologies.

Allocation

Many times, unit processes have outputs that are not used in the downstream processes of the system being studied. When that happens, the question arises how to account for the environmental impacts of the different outputs of the unit process. The ISO standards prefer the use of system boundary expansion over simple allocation of the different emissions on the basis of weight or some other parameter. The group decided to use system boundary expansion to account for multiple outputs, with a fallback of allocation according to mass when system boundary expansion is impossible.

One can only do system boundary expansion when the secondary products of a unit process can displace another product with a different and unallocated life cycle. For example, the fly ash from a coal-fired power plant is often used in place of lime for the production of cement. Expanding the system boundary means that one calculates the impacts of producing lime and of making electricity from coal, and from the impacts of the production of electricity subtract the impacts of the production of lime equivalent to the relevant amount of fly ash. This leaves only the environmental impacts proper to the production of electricity itself.

Sometimes it is impossible to perform system boundary expansion, for example in the production of petroleum many products are produced in the cracking process. They cannot substitute for another product, and therefore allocation of the various environmental impacts to the different products is appropriate. For this scoping exercise, the group decided that in the event that system boundary expansion is impossible, allocation should be made according to the mass of the product.

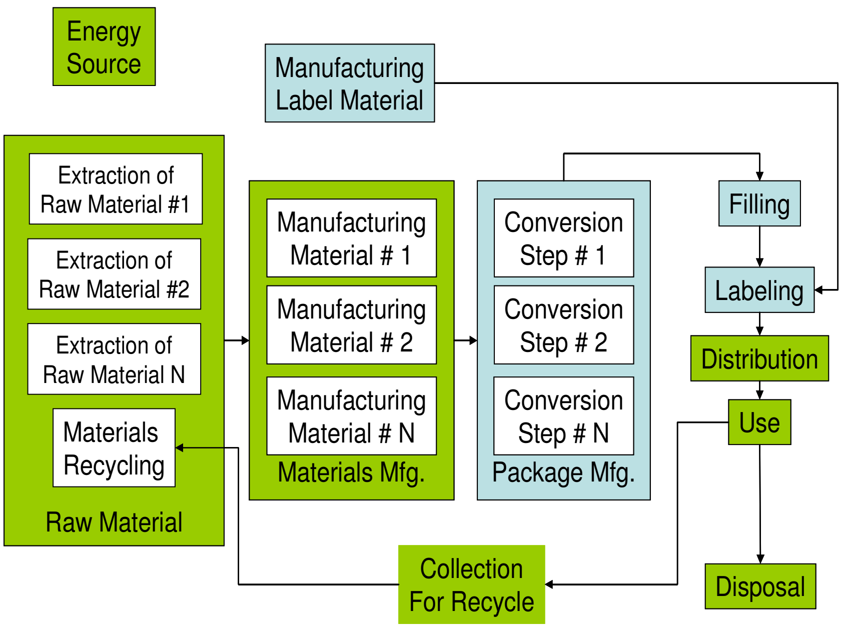
There are some life cycle experts who prefer cost allocation, where multiple outputs of a unit process are allocated according to the monetary value of the outputs. The ISO standards permit this form of allocation, but as the least preferred method of allocation. The prices of different products can vary substantially over very short time frames and therefore are not a stable way to allocate environmental impacts. In contrast, process improvements tend to occur much more slowly over years or decades, and therefore make the mass-allocated data valid over that time frame.

Life Cycle Inventory (LCI)

Gathering the life cycle inventories is the most time consuming part of a life cycle assessment study. Each unit process has inputs and outputs that must be estimated. Ideally, the statistical distribution of each parameter should be characterized, in order to permit evaluation of the statistical significance of the outcomes. The ISO standards require that many decisions be explicitly made about the data gathering process, and that these be listed transparently.

Types and sources of data

Figure 8 Foreground and background data



Quantified flows into and out of unit processes are called life cycle inventory data. When performing a life cycle assessment, one typically gathers new data and combines it with data available from other data sources. The new data focuses on the unit processes of particular interest, and is called the foreground data. The other data is called background data and typically comes from commercial and governmental databases. Figure 8 shows the foreground unit processes in blue, with the background processes in green.

The group decided that background data should be taken from the US LCI database, and when the relevant information was not available there it should be taken from the Ecoinvent database.

It further decided that unit process data developed for this food packaging process should be placed into the US LCI database. These decisions were made because it was perceived that this data was the most relevant and the least costly source of data for LCAs performed in North America. Once data is placed into the US LCI database, it is free for anyone to use.

Data Quality Planning

There are many dimensions of data quality: the ISO standards demand that the following be specified:

- Age
- geography
- technology coverage
- precision

- industry coverage
- representativeness
- reproducibility
- sources of the data
- uncertainty of the information

Exactly how items are produced changes all the time. Industries become more efficient and new technologies are developed daily. For this reason, one typically prefers to use LCI data that is no more than five years old. The group chose five years as the cutoff, with the proviso that if it was known that the technology had not changed, older data could be accepted.

As noted above, the group addressed its effort toward packages whose final manufacturing step was in the USA or Canada. Of course, some materials are not manufactured within these geographic confines, but it was assumed that these materials and processes could be obtained from data in the Ecoinvent database. Where data was not available either from the US LCI database or from peer-reviewed published studies, primary (foreground) data should be gathered.

Many LCI data gathering exercises are designed to cover a fixed fraction of an industry's production. However, the packaging industry is very diverse with hundreds of small manufacturers doing similar processes. In this case a statistical sampling is not only appropriate, but less costly and probably more accurate than other sampling schemes. The group decided that sampling for packaging processing should be performed via a random sampling of producers, where necessary a stratified random sampling should be performed to achieve a 95% confidence interval.

A random sampling also provides the opportunity to calculate the mean, standard deviation and test the normality of the different LCI results. It is an approach that neatly covers all the ISO requirements for precision, representativeness, coverage, reproducibility, data sources and uncertainty. It also provides the necessary data for future tests of robustness of study assumptions. Its disadvantage is that it is impossible to perform site-specific impact modeling, but this is the norm for LCI data.

Life Cycle Impact Assessment (LCIA)

Once LCI data is gathered, one can perform the impact assessment. This step of the LCA process uses life cycle inventory results to provide an indicator of the impact of the emissions and resource consumption caused by the product being studied. A first step is to decide which environmental issues a study should cover. The issues are called impact categories. The group picked a fairly typical but quite comprehensive list of impact categories, as shown below.

- Climate Change
- Eutrophication

- Photochemical Smog
- Acidification
- Human Toxicity
- Eco-Toxicity
- Water Resource Depletion
- Mineral Resource Depletion
- Fossil Fuel Depletion
- Land Use /Biodiversity
- Soil Depletion

One impact category was specifically excluded: stratospheric ozone depletion. It was thought that this environmental issue was being well managed already. Ozone depleting substances are being phased out of production per an international treaty (the Montreal Protocol), and the ozone layer is slowly recovering. Including ozone depletion in these studies would add cost without influencing environmental outcomes.

Some of the impact categories shown above were chosen not because they were expected to be important for the packaging, but because they are important for the food inside the packaging. For example, land use for manufacturing is small, but land use for agriculture is large and the land occupation itself is the largest source of the impact of food production.

Impact indicators and models

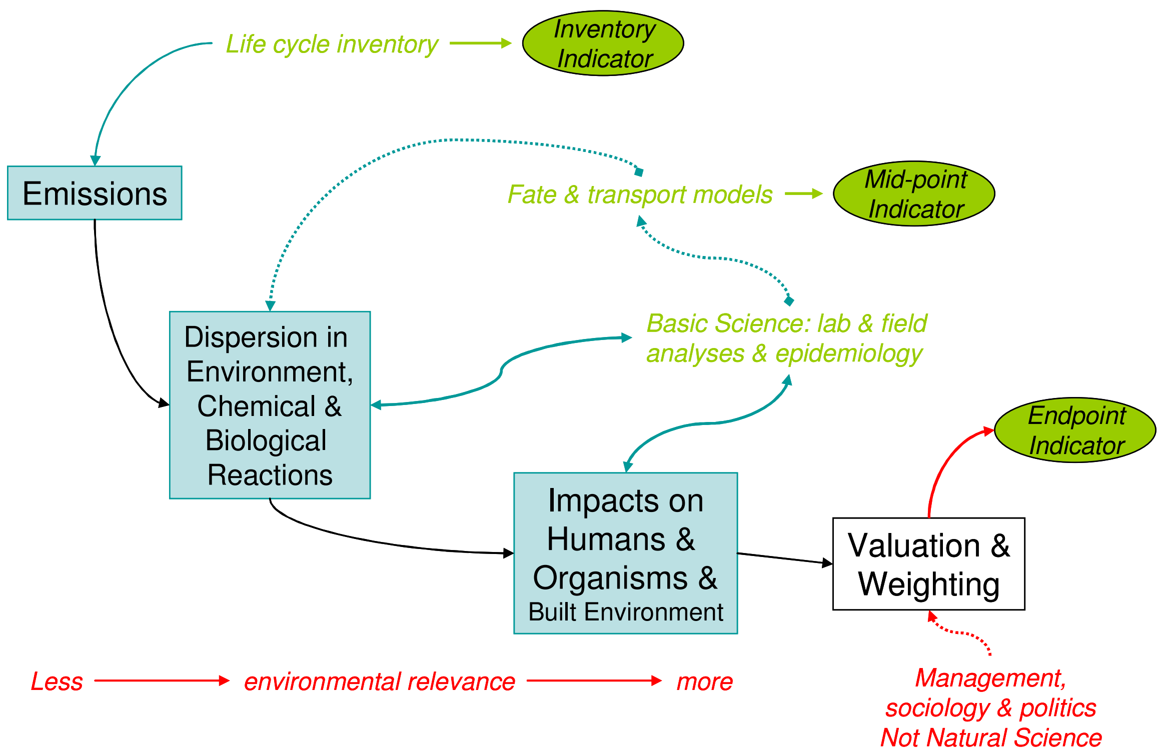
When a substance is emitted into the ecosphere, it undergoes transport and modification, often in many steps before it has an effect on the biosphere. The entire chain of events is called the environmental mechanism. Scientists study these physical, chemical and biological processes to understand how nature works, and after the mechanism is understood well enough they can develop models of the behavior of substances in the environment. These are called fate and transport models. Life cycle experts use the outputs of these models to develop characterization factors for the emissions of substances along the life cycle.

Resource consumption is comparable to emissions of pollutants, but the issues are somewhat different. Questions of the size of a natural resource base, the flow of the resource and whether and how it is being renewed or recycled, all figure into the environmental mechanism behind the use of a resource.

The ISO standards permit one to choose indicators that are developed at any point along the environmental mechanism from the point where the emission and resource consumption occur (inventory indicators) through all the intervening steps (midpoint indicators) to final impact (endpoint indicators). Indicators that are close to the end of the environmental mechanism are said to be more environmentally relevant than those that are close to the beginning of the environmental mechanism.

In general, inventory indicators are more precise, but there is less assurance that they correlate with the impact in question. Mid-point indicators correlate better with the

Figure 9 Life Cycle Impact Indicators Scheme



impact in question, but they are less precise (i.e. they have higher uncertainty). Endpoint indicators require a non-science-based judgment or valuation to combine impacts that are inherently different. For example, indicators of ecosystem health require one to combine such disparate impacts as land use and acid rain.

Figure 9 illustrates the scheme for life cycle impact assessment indicators. The state of the science behind each impact category is quite variable. For some categories there are very good models and a quite high level of certainty that the indicator correlates well with the impact of concern. For others, we have very little understanding and a corresponding low level of certainty that the indicators correlate well to the impacts about which we are concerned.

The ISO standards require that for claims of overall environmental superiority of one product versus another, only natural-science-based indicators may be used, and the comparison must be category by category. What this means is that any such claim must be based on inventory and/or mid-point indicators and every indicator category must be better in one case than in the other. This kind of a claim is called a comparative assertion, and this food package scoping exercise is specifically not designed to address comparative assertions. Nevertheless, the decision was made to avoid endpoint indicators because they are not science-based.

Climate Change

The issue of climate change is probably the most intensively studied environmental impact category, and therefore the indicators are the most reliable and the most accurate of any of the impact categories. Climate change is a global impact: greenhouse gases are emitted into the atmosphere, where they mix globally, and they absorb and re-radiate infrared radiation to act as a heat blanket for the earth. The potency of a greenhouse gas is dependent on its infrared absorbance and its residence time in the atmosphere.

Since 1995, the Intergovernmental Panel on Climate Change (IPCC) has been providing estimates of the global warming potential of different greenhouse gases looking at different time horizons, and expressed it in units of CO_2 (carbon dioxide) equivalents. Standard practice in the LCA community is to use the 100-year time horizon. One hundred years is the approximate residence time of CO_2 in the atmosphere. The scoping group adopted this time horizon as well. Although climate change effects are seen locally, the mid-point indicator of CO_2 equivalents does not account for regionalization, and this helps increase the precision of the results.

Different efforts within Wal-Mart have chosen to use different IPCC reports as the basis of the global warming potential. The Packaging Sustainable Value Network uses the 1996 factors, while the Wal-Mart footprinting effort is expressed using the 2007 factors.

Table 1 Example Global Warming Potential Values

Substance	1996 Factor	2007 Factor
Methane CH_4	21	25
Nitrous Oxide N_2O	310	298
HFC 23	11,200	14,800
Sulfur hexafluoride SF_6	23,900	22,800

Table 1 illustrates the differences in the global warming potential factors for a few greenhouse gases. While the differences between the different reports are small, the group recommended that the more recent figures be used to preserve the technical strength of the indicator.

Acidification, Photochemical Smog and Eutrophication

The impact categories of acidification, photochemical smog and eutrophication share several characteristics. All of them:

- are based on emissions,
- include oxides of nitrogen in their environmental mechanisms,
- describe regional-scale impacts, and

- are based on complex interactions with sunlight and with other chemical species.

Appropriate modeling of the environmental mechanisms for these three impact categories is complex, but reasonable well understood.

Acidification occurs because certain substances (such as oxides of sulfur and nitrogen) are emitted into the air where they undergo chemical transformation. Then they are deposited through wet and dry deposition on soils and buildings. Some soils have enough acid neutralizing capacity to neutralize the acid, and therefore limit environmental impacts. Some building materials, e.g. limestone and concrete, are easily dissolved under acid conditions, and they become eroded away.

If the acid deposition is not neutralized, the acid dissolves the metals in the soils, especially aluminum. This metal is toxic to both plants and aquatic animals (especially fish) and is the primary agent in the death of trees and lakes in areas where there is little acid neutralization capacity in the soils coupled to high acid deposition.

Photochemical smog occurs when oxides of nitrogen in the air interact with volatile organic substances in the presence of sunlight to create ozone and other toxic chemical species. The time needed to complete this reaction is on the order of days, and so peaks in ozone concentration tend to be found hundreds of miles downwind of large cities. Ozone is an increasing problem in rural areas, where natural levels of organic substances interact with oxides of nitrogen to produce smog.

Ozone and other smog elements can cause injury to lungs, including asthma and lung cancer and reduce plant primary production.

Eutrophication is the overgrowth of algae in the water column due to the excess of a limiting nutrient. This leads to several undesirable outcomes. First, the relative concentration of different algal species changes: this can have ripple effects along the aquatic food chain. Second, toxic algal blooms may occur where nutrients allow. Third, the algal bloom is followed by removal of oxygen in the water column, and in some cases this leads to fish kills or even full anaerobic conditions in the water column. This is happening on a massive scale in the Gulf of Mexico.

Typically, nitrogen is the limiting nutrient in salt water and phosphorus is the limiting nutrient in fresh water. However in some areas nutrient loading changes this situation. An example is Chesapeake Bay, where phosphorus is the limiting nutrient because extensive deposition of nitrogen compounds has reversed the usual state.

For these three impact categories the group decided to apply the models and characterization factors of TRACI, the life cycle impact assessment model developed by the U.S. EPA. TRACI contains regional factors for different areas of the US and Canada, but the regional factors will not be applicable for the kind of data collection planned for the food container situation, because the data will be collected from sites across the USA and Canada. In addition, much of the background data in the US Life Cycle Inventory

Database and elsewhere is not site-specific. As a result, the national average factors contained in TRACI will have to be used.

The group noted that TRACI is not a transparent, verifiable system, but must be treated as a black box. It was felt that this limited the technical strength of the models, leading to an overall moderate confidence in them. There was relatively high confidence that the science behind the model was reasonably well understood, but that the non-transparency of the models and the inherent regionality of the impacts means that there will be substantial uncertainty to the results.

Human and Ecotoxicity

In some ways, toxicity is the most troubling of the impact categories. There are many, many knowledge gaps in the environmental mechanism of different toxicants. The bioavailability of a substance is controlled by many physical, biological and chemical parameters, and the outcomes of the exposure can vary from slight to fatal, based on the exposure mechanisms, the species in question and even the health and unique biology of the exposed individuals.

When one considers that there is very little epidemiological data on human reactions to toxic substances it becomes clear that there is yet another layer of uncertainty. Human toxicity factors are almost uniformly based on rodent toxicity studies, since deliberate exposure of human beings to toxic substances is clearly unethical. The situation in ecotoxicity is similar, for only certain species are tested, and these represent not the most sensitive species, but usually the most robust species that are easy to culture in the laboratory. Ecotoxicity studies typically only evaluate mortality, although there are as many potential health impacts in other species as in the human population. The response of organisms to a given toxicant is very species-dependent, and covers over ten orders of magnitude.

Neither the human nor the eco-toxicity portions of USE-tox adequately characterize the toxicity of inorganic substances such as metals.

Recognizing that any toxicity assessment will have very large (order of magnitude) errors, the group chose to recommend the USE-tox models. These models are based on a fugacity model coupled to estimates of toxicity. A fugacity model partitions chemicals into different environmental compartments, providing a “unit world” view of fate and transport. The fugacity model is especially powerful in the case of ecotoxicity, because all compartments of the environment contain organisms potentially exposed to toxicants. A fugacity model is less useful in the case of human toxicity, because except in the case of very long-lived organic substances, human toxicity is very site-specific, and releases into the environment in rural areas can be expected to have few human receptors of concern.

In the case of ecotoxicity the LC-50 or EC-50 is used as a measure of toxicity. This is the water concentration at which 50% of a given species population dies, or at which growth rates are reduced 50%. In the case of human toxicity, the endpoints are variable, but all are expressed in units of disability-adjusted life years (DALYs).

DALYs are derived from a set of value judgments made by a panel of experts convened by the World Health Organization. Thus the human toxicity portion of USE-tox is an endpoint indicator. Despite that fact, the group thought that the approach was the best available to combining human health factors for a wide variety of toxic chemicals.

Neither the human nor the eco-toxicity portions of USE-tox adequately characterize the toxicity of inorganic substances such as metals. This is due in large part because these substances are elements, which do not degrade, while USE-tox is based on models of organic substance which do degrade. Estimates of bioconcentration of heavy metals as imbedded in fugacity models are also incorrect. While some metals such as mercury do indeed have a high bioavailability and bioconcentration factor, most of the heavy metals in the environment are poorly bioavailable, and do not bioconcentrate up the food chain. Studies by the US EPA and others have suggested that by and large, heavy metals should be assumed not to bioconcentrate.[1] More details can be found at the EPA's Framework for Metals Risk Assessment.

In summary, while USE-tox is the best available life cycle impact assessment model for toxicity, there are many potential sources of errors, especially in the human health portions of the models. ***Users should exercise extreme caution when evaluating the toxicity impacts of products, for the uncertainty covers orders of magnitude***.

Fossil Fuel Depletion

The group decided that the best choice to measure fossil fuel depletion is that embodied in the TRACI model. There is a high level of confidence for this model since it simply adopts the approach of Guinée et al. In general there is a high level of confidence in the inventory figures that feed into the model (the use of each type of fossil fuel).

The impact is calculated as excess energy required to obtain the fossil fuel in question. The logic is that as reserves become depleted, it takes more and more energy to develop the reserve, and eventually it will take more energy to obtain the fossil fuel than is contained in the fuel. There is somewhat less confidence in this measure than in the inventory data, since the energy intensity of the fossil fuel extraction is not always known.

[1] IERE has developed a model for ecotoxicity that accommodates the characteristics of heavy metals and other inorganic substances. The model and an automated calculation engine can be found at www.iere.org/lca-tox.

Land Use and Biodiversity

Land use is clearly the most important impact of human beings on the planet. In the USA, 90% of the land area is in commercial use. In Europe, the figure is 99%. Human use of land decreases biodiversity, sometimes in a gross sense, as in the production of monoculture row crops, and sometimes simply by using the primary productivity and thus depriving other species from adequate resources to thrive.

Despite the importance of this impact category, there is little consensus about how to measure it. The TRACI methodology applies a factor for the areal frequency of threatened and endangered species, on a regional basis. In the case of national average LCI data this collapses to a single average factor: the indicator becomes an inventory indicator.

The group agreed that the inventory for land occupation was relatively easy to obtain and accurate, and that therefore there is high confidence in this indicator. However, there was also agreement that the impact of land occupation on biodiversity was poorly characterized.

Water Resource Depletion

The importance of water use can hardly be underestimated. All life depends on it, and in the USA, it is clear that freshwater water resources are being depleted: the Colorado River and the Rio Grande no longer reach the ocean because the water is being siphoned off for agriculture and other uses. The TRACI system accounts for the water use as another inventory indicator and the group agreed to support this approach.

However, there is a large variability in the manner in which this data is collected. Sometimes all withdrawals are measured, sometimes saltwater withdrawals are measured, and other times only net withdrawals are measured. The group noted that the appropriate inventory data to indicate water depletion is the **net** water use: the freshwater that is used and not returned to another freshwater stock, such as a river or lake. This is sometimes called consumptive use.

Mineral Resource Depletion

Depletion of mineral resources has an obvious effect on industry in terms of costs and (when a mineral becomes depleted) the need to find another mineral or technology to accomplish desired goals. The group decided to use the inventory of minerals used as the indicator. In order to not have an overwhelming amount of data reported under this category, the group decided to only report on the minerals with less than 200 years proven reserve, as measured in the USGS Minerals Commodities Summaries. These are listed in Table 2.

Table 2 Minerals with Less than 200 Years Reserve

Mineral or product	Years Reserve at 2007 mining rate		Mineral or product	Years Reserve 2007 mining rate
Aluminum	132		Mercury	31
Antimony	16		Molybdenum, Mo content	48
Arsenic trioxide	20		Nickel, Ni content	40
Bauxite	24		Niobium	60
Bismuth, refinery	56		Phosphate rock	122
Boron minerals	40		Platinum-group metals	153
Cadmium, refinery	25		Selenium	53
Chromite	8		Silver	13
Cobalt, Co content	112		Strontium	11
Copper	31		Tantalum	93
Diamonds (industrial)	8		Tellurium	156
Fluorspar	45		Thallium	38
Gold	17		Tin	20
Graphite (natural)	83		Titanium	120
Indium	22		Tungsten, W content	23
Iron ore	79		Yttrium	61
Lead	22		Zinc	17
Lithium	164		Zirconium	31

Soil Depletion

Disturbance of soils promotes wind and water-based erosion. This occurs whether the soil disturbance is plowing, mining, forestry, construction or other activity. All terrestrial life depends on the fertility of the soil, and therefore maintaining soil integrity is essential to maintaining life. Soil fertility can be affected by many factors besides erosion. For example, irrigation can lead to salinization of soils, or to concentration of toxic elements such as aluminum or selenium. The group felt that simple erosion was a better way to look at soil depletion, in large part because the other impacts are too site-specific to fit into the non-site-specific LCI approach.

Several different indicators have been developed to look at soil depletion, however simple erosion of soil from the site was chosen as the impact indicator. This can be calculated on an area-specific basis with the Universal Soil Loss Equation[2] or other means available through the peer-reviewed literature.

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[2] http://www.iwr.msu.edu/rusle/ provides examples and software for calculating soil loss.

Impact Indicator Models Summary

In general, the group opted for inventory indicators for resource impacts, and mid-point indicators for emission impacts. As described earlier, an exception is made in the case of human toxicity, where the accepted indicator is DALYs, an endpoint indicator. Where standard models exist, they were applied. The group realized that there is a wide difference in the reliability of the different impact models.

Table 3 below shows the decisions that were made vis-à-vis the different impact category models.

Table 3 Impact Assessment Models Chosen

Impact Category	Model Chosen	Type of Indicator
High Confidence Models		
Climate Change	IPCC-100 yr	Midpoint
Water Resource Depletion	Net freshwater use[3]	Inventory
Mineral Resource Depletion	Use for minerals with < 200 years reserves	Inventory
Fossil Fuel Depletion	TRACI	Midpoint
Land Use /Biodiversity[4]	Area occupied	Inventory
Soil Depletion	Mass of soil eroded from site	Inventory
Moderate Confidence Models		
Eutrophication	TRACI	Midpoint
Acidification	TRACI	Midpoint
Photochemical smog	TRACI	Midpoint
Low Confidence Models		
Human Toxicity	USE-tox	Endpoint
Ecotoxicity	USE-tox	Midpoint

As noted above, there is not always complete transparency in available life cycle impact assessment models. Some of that is due to the technical difficulty of the modeling process, and some of that is due to lack of funding to develop models with technical rigor and transparency. In as much as sustainability is a key issue of our times, and LCA is the appropriate tool to measure it, the group is anxious to see real progress in this area.

[3] The group noted that there is little clarity in existing datasets as to whether the inventory data is based on net water use or some other measure. There is high confidence in the indicator, but relatively low confidence in the existing data.
[4] Note however, that there was little confidence that land occupation was a good predictor of biodiversity loss.

There are also issues in the life cycle inventory data transparency reproducibility and even nomenclature. Until these issues are addressed there will always be a barrier to the production of good life cycle assessments. This scoping effort has made a point of clearly stating how inventory for soil loss and water use should be accounted for. We trust that this guidance will help to clarify at least these issues.

Users of LCA results should exercise caution in evaluating differences between scenarios, and this is especially important in the case of toxicity issues.

Report and Critical Review

The group made the decision that the primary report format should be a spreadsheet that would allow easy use by package manufacturers and others. A spreadsheet would permit a mix-and-match approach to making packaging decisions and provide a simple to use screening tool. The group supported the use of the International System of Units (SI units, or metric units).

Often, further analysis of the data can help in interpretation of the results. LCA studies commonly include a gravity analysis, or a comparison among the different parts of the life cycle in order to find hotspots. Simple gravity analysis of the packaging life cycle stages or unit processes was thought not to be useful in this context. Normalization compares the results to a common baseline to put the outcomes of the study into context. In general, the group thought that normalization of the results for each container would be most useful if they were compared relative to the contents of the container, rather than to another container.

Some of the other potential analytical techniques, such as weighting to obtain a single score, were inappropriate because they are values-based rather than science-based analyses.

The group supported a peer review process that conformed to the requirements of ISO 14040, 7.3.3. This means a review panel of at least 3 people. The critical review would be directed to the spreadsheet and ancillary documentation. In particular it would review whether the report supported the scoping described in this document.

Environmental Product Declarations

One potential use of an LCA study is to support environmental product declarations (EPD), also know as Type III Ecolabels. The group noted that the LCA scoping it completed provides an excellent basis to support an environmental product declaration, and encourages others to use this document as the basis of such an ecolabel. However, it did not incorporate the development of an EPD in this exercise.

Summary and Conclusions

Life cycle assessment is an analytical technique designed to measure the environmental sustainability of products. It does this by measuring a full set of environmental impacts over the entire life cycle of the product. It is a strong and flexible tool, and the best available for this purpose.

This document describes a multi-stakeholder life cycle assessment scoping exercise which over the course of a half-year brought together a wide range of experts, industry competitors and interested parties. There was a wide range of expertise going into the process. Some participants were LCA experts, while others had never participated in an LCA study.

The effort was reasonably low-cost, and quick[5]. We attribute the success of the process to several factors:

1. Market Drivers: Supporting the Wal-Mart effort and increasing its value was a strong driver for the participants.
2. Consensus and Transparency: All decisions were made through open discussion: the parties took straw-man votes and verified them through their organizations.
3. Adherence to Principles: Decisions were made to support technical strength, to provide a level playing field, and to control costs. In this matter, the participants could all see the value to their organizations.
4. Clarity of Agenda: From the beginning, the effort focused on the requirements of the ISO Standards. This focus made the application of the principles easier.

The most difficult part of the scoping was decisions made on category impact models. The state of the science on different categories is quite variable, and this is reflected in the level of confidence the group placed in the different models they chose. Comparisons among products over these impact categories must be done with care: the uncertainty is high and in many cases the life cycle impact results must differ by more than an order of magnitude in order to assure there is a statistically significant difference between products. Nevertheless, in the spirit that it is more important to be complete than to be precise, the group chose a large range of impact categories to evaluate.

The outcome of this effort is a full scoping for a primary food container. However, many of the lessons learned and the decisions made are applicable to many other kinds of products: other containers and packaging, other products, other locations. One potential and desired use is for this scoping document to be used for other LCA studies, to simplify the scoping process even further.

To assist in this use, Table 4 lays out all the decisions made, the relevant ISO references, and the applicability of the decision on a geographic and on a product basis. One can identify the scoping decisions that are not covered in this document by choosing the geographic and product columns relevant to the LCA one is scoping. Where there are

[5] Minutes and supporting documents on the process are available at www.iere.org/scoping/index.html

blanks in either the blue or the green columns, a new scoping decision will have to be made to cover the particular LCA one is performing.

Some of the participants of this exercise are already undertaking LCA studies that will conform to this scoping document.

As another outcome of this project the group has some recommendations for Wal-Mart in support of their packaging sustainability scorecard.

1. The entire life cycle (including the contents of the package) should be included in the greenhouse gas analysis portion of the scorecard.
2. The results of the LCA should be expressed in terms of the functional unit of the product, rather than in terms of the mass of the product or packaging. Wal-Mart's Packaging scorecard has made a move in this direction by identifying consumer-meaningful units of measure (CMUMs).
3. LCA is designed to measure the sustainability of products. The sustainable materials category should be replaced by some combination of the other life cycle impact indicators, over the entire life cycle.
4. Wal-Mart should recognize in their scoring process that not all impact indicators are created equal, and that in some cases the error bars around the indicators can be very large.

The same advice may be proffered to Wal-Mart's efforts towards a scorecard for all the products it purchases. Using a life cycle approach is essential to achieving sustainability, and the group applauds Wal-Mart's adoption of this approach. The corporations that embrace and move towards understanding their sustainability impact on a holistic and science-based LCA approach are the one who will have a great advantage: they will be able to make the world more sustainable and also make themselves more profitable.

Table 4 Summary of Scoping Decisions

Required Point for ISO 14040/44/25	Scoping Decisions	Decision Applicability: Geography – USA/ Canada	Decision Applicability: Geography – Global	Decision Applicability: Product – Food Containers	Decision Applicability: Product – All Packaging	Decision Applicability: Product – All Products
The intended application 14040: 5.2.1.1; 14044:4.2.2	Supporting Wal-Mart's sustainable packaging program's scorecard second phase: Provide assistance to all commissioners of LCAs for packaging;					
The reasons for carrying out the study 14040:5.2.1.1; 14044:4.2.2	To assure a level playing field for all industry players & to model future LCA scoping work. To provide a stand alone guidance to assure open, transparent and comparable LCA studies on packages, starting with food primary packaging. To provide an important basis for Environmental Product Declarations for Packaging.					
The intended audience, i.e. to whom the results of the study are intended to be communicated 14040: 5.2.1.1; 14044:4.2.2	Wal-Mart and their vendors are the primary audience. B to B and government regulators are secondary audiences					
Whether the results are intended to be used in comparative assertions intended to be disclosed to the public. 14040:1.2.1.1; 14044:4.2.2; 14025:5.2.2	No comparative assertions are intended.					
Product system to be studied 14040:5.2.1.2; 14044:4.2.3.1	Primary food containers					
Functions of the product system 14040: 5.2.1.2; 14044:4.2.3.1	Permit shelf storage of food for retail size multi-serving containers (i.e. about 16 ounces)					
Functional unit 14040: 5.2.1.2; 14040:5.2.2; 14044:4.2.3.1; 14044:4.2.3.2	Ounces of contained food shelf stable for at least 12 months					
System boundary 14040: 5.2.1.2; 14040:5.2.3; 14044:4.2.3.1; 14044: 4.2.3.3.1	Cradle to grave, per flow charts					

Required Point for ISO 14040/44/25	Scoping Decisions		Decision Applicability				
			Geography		Product		
			USA/ Canada	Global	Food Containers	All Packaging	All Products
Unit Process Descriptions 14044: 4.2.3.3.2	Needed for each package separately						
Allocation procedures 14040: 5.2.1.2; 14040:5.3.4; 14044:4.2.3.1	Allocation avoided through system boundary expansion. Where that is not possible, mass allocation is to be used.						
Impact categories selected and methodology of impact assessment, and subsequent interpretation to be used; 14040: 5.2.1.2; 14044:4.2.3.1; 14044:4.2.3.4; 14025:5.3.1; 14025:6.2	**Impact Category**	**Model**					
	climate change	IPCC 2007 factors, 100 year horizon					
	acidification	TRACI					
	eutrophication	TRACI					
	photochemical smog	TRACI					
	human toxicity	USE-tox (or Wal-Mart's choice)					
	ecotoxicity	USE-tox (or Wal-Mart's choice)					
	water resource depletion	Net freshwater use					
	mineral resource depletion	Mineral use for reserves<200 years					
	fossil fuel depletion	TRACI					
	land use/biodiversity	Area of land occupied					
	soil depletion	Mass of soil lost from site					
Interpretation 14040: 5.2.1.2; 14044:4.2.3.1	Data should be disclosed relevant to the contents of the container: Normalization to the LCIA results of the food is appropriate.						
Types and sources of Data 14044:4.2.3.5	Where possible, US LCI database, otherwise the Ecoinvent database.						
data quality requirements 14040: 5.2.1.2**;** 14044:4.2.3.1; 14044: 4.2.3.6.2; 14025:5.5							
age	No data over five years old, unless it can be documented that the unit process has not changed.						

Required Point for ISO 14040/44/25	Scoping Decisions	Decision Applicability				
		Geography		Product		
		USA/ Canada	Global	Food Containers	All Packaging	All Products
geography	USA and Canada					
	Cutoff values: 99% of the mass and energy in the system: all known toxicity issues addressed 14044: 4.2.3.3.3					
technology coverage	Addressed statistically					
precision:	Addressed statistically					
industry coverage	Statistically valid sampling of all relevant unit processes for packages where the final conversion step is in the USA or Canada					
representativeness	Data collected over a 12-month period to accommodate the growing period					
reproducibility	Reported on statistical sampling					
sources of the data	Primary data or peer-reviewed published data preferred. US LCI Database backed by the Eco-invent Database					
uncertainty of the information	Reported in mean, standard deviation, number of samples and tests of normality					
Assumption: 14040: 5.2.1.2; 14044:4.2.3.1	LCA's of the contents in the containers should also be done.					
Value Choices: 14044:4.2.3.1	Only midpoint & inventory indicators used to limit value choices					
Limitations 14040: 5.2.1.2; 14044:4.2.3.1; 14044:4.2.3.1	Analysis is based on industry averages					
Initial data quality requirements 14040:5.2.1.2; 14044:4.2.3.1; 14025:5.5	Data no more than 5 years old; published peer-reviewed data where possible, data sets where not possible: sources should be disclosed.					
Type of critical review, if any 14040:5.2.1.2; 14044:4.2.3.1; 14044: 4.2.3.8; 14025:5.2.1	Per ISO 14040:7.3.3, at least a 3-person review panel					
Type and format of the report required for the study 14040:5.2.1.2; 14044:4.2.3.1	Data should be expressed in a spreadsheet format that provides industry-average data, rather than manufacturer-specific data.					

Required Point for ISO 14040/44/25	Scoping Decisions	Decision Applicability				
		Geography		Product		
		USA/ Canada	Global	Food Containers	All Packaging	All Products
	New data collection should be input into the U.S. Life Cycle Inventory database.					
	Where possible, Data from the US LCI database should be used.					
	Reports should be in metric units.					
EPD Requirements per ISO/TR 14025	Although the scoping can be used for an EPD, the group does not intend to develop one themselves.					

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