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ISO 14040 Life Cycle Assessment (LAS) as a Tool for Effective Environmentally Friendly Waste Management in the Food Industry

3.1 Introduction

The increased awareness of the importance of environmental protection, and the possible impacts associated with products both manufactured and consumed, has increased interest in the development of methods to better understand and address these impacts. One of the techniques being developed for this purpose is lifecycle assessment (LCA). LCA can assist in

- identifying opportunities to improve the environmental performance of products at various points in their life cycle,
- informing decision-makers in industry, government or non-government organizations (e.g. for the purpose of strategic planning, priority setting, product or process design or redesign),
- the selection of relevant indicators of environmental performance, including measurement techniques, and
- marketing (e.g. implementing an Eco labelling scheme, making an environmental claim, or producing an environmental product declaration).

For practitioners of LCA, ISO 14044 details the requirements for conducting an LCA. LCA addresses the environmental aspects and potential environmental impacts (e.g. use of resources and the environmental consequences of releases) throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal (i.e. cradle-to-grave). There are four phases in an LCA study:

- The goal and scope definition phase,
- The inventory analysis phase,

- The impact assessment phase, and
- The interpretation phase.

The scope, including the system boundary and level of detail, of an LCA depends on the subject and the intended use of the study. The depth and the breadth of LCA can differ considerably depending on the goal of a particular LCA. The life cycle inventory analysis phase (LCI phase) is the second phase of LCA. It is an inventory of input/output data with regard to the system being studied. It involves collection of the data necessary to meet the goals of the defined study. The life cycle impact assessment phase (LCIA) is the third phase of the LCA. The purpose of LCIA is to provide additional information to help assess a product system's LCI results so as to better understand their environmental significance. Life cycle interpretation is the final phase of the LCA procedure, in which the results of an LCI or an LCIA, or both, are summarized and discussed as a basis for conclusions, recommendations, and decision-making in accordance with the goal and scope definition. There are cases where the goal of an LCA can be satisfied by performing only an inventory analysis and an interpretation. This is usually referred to as an LCI study. This International Standard covers two types of studies: life cycle assessment studies (LCA studies) and lifecycle inventory studies (LCI studies). LCI studies are similar to LCA studies but exclude the LCIA phase. LCI studies are not to be confused with the LCI phase of an LCA study. Generally, the information developed in an LCA or LCI study can be used as part of a much more comprehensive decision process. Comparing the results of different LCA or LCI studies is only possible if the assumptions and context of each study are equivalent. Therefore this International Standard contains several requirements and recommendations to ensure transparency on these issues. LCA is one of several environmental management techniques (e.g. risk assessment, environmental performance evaluation, environmental auditing, and environmental impact assessment) and might not be the most appropriate technique to use in all situations. LCA typically does not address the economic or social aspects of a product, but the life cycle approach and methodologies described in this International Standard can be applied to these other aspects.

3.2 Description

Every day in the marketplace, people make choices that affect, directly or indirectly, the environment. Manufacturers choose from among different materials, suppliers, or production methods. Consumers, for their part, either choose among products or whether to use a product at all. Those who would like to make environment ally responsible choices need reliable information which is frequently related to life cycle assessment (LCA) (http://www.tc207.org/articles/). LCA considers the environmental aspects and the potential impacts of a product or a service system throughout its life - from raw material acquisition through production, use, and disposal (from cradle to grave). This information is very important and can be of great help in identifying ways to improve environmental aspects of a product at various stages in its life cycle, to support decision-making in industry, governmental or non-governmental organizations. It can substantially help the selection of various indicators of environmental performance (EP) and (with proper precautions) to promote the marketing of products or services (EPA, 1994). The Society for Environmental Toxicology and Chemistry (SETAC) defines LCA as the:

Process to evaluate the environmental burdens associated with a product, process, or activity by identifying and quantifying energy and materials used and wastes released to the environment; to assess the impact of those energy and material uses and releases to the environment; and to identify *and evaluate opportunities to effect environmental improvements. The assessment includes the entire life cycle of the product, process or activity, encompassing extracting and processing raw materials; manufacturing; transportation and distribution; use, re-use, maintenance; recycling; and final disposal (EPA, 1994).*

The main focus of LCA is to determine the environmental impacts of the system understudy in the areas of ecological well-being, human health, and resource depletion (Tansey and Worsley, 1995). ISO 14041 is entitled 'Life Cycle Assessment – Goalsand Definition/Scope and Inventory Analysis' and is intended to describe the special requirements and guidelines for the preparation, conduct and critical review of the lifecycle inventory analysis. The most widely accepted LCA structure is the one suggested by SETAC as described in Table 1.0. The term 'life cycle analysis' is often employed for the analysis stage of a life cycle assessment. Goal definition (ISO 14040) is perhaps the most important component of LCA. The inventory (ISO 14041) is an analysis, qualitative and/or quantitative, of the resources used and the emissions generated in the life cycle. The impact assessment (ISO 14042) can be divided into classification, characterization, and valuation (Andersson *et al*., 1994). The assessed impacts fall into three broad categories: human health, ecological health, and resource use (Tansey and Worsley, 1995). Characterization is the aggregation of inventory data within the impact categories by the use of equivalency factors (Andersson *et al*., 1994). It is a largely quantitative step that analyses the relative contribution of the multiple inputs or outputs by category (Tansey and Worsley, 1995). Valuation can be carried out either qualitatively or quantitatively by expert panels or by comparison of environmental loading profiles, respectively (Andersson *et al*., 1994; Boudouropoulos and Arvantioyannis, 1999). Interpretation (ISO 14043) stands for conclusions based on the assessment and suggestion of improvement actions.

Table 3.1 *Structure of LCA suggested by the Society of Environmental Toxicology and Chemistry (SETAC) Source: Andersson et al., 1994, Tibor and Feldman, 1997.*

Analysis	Goal definition and scooping Inventory analysis
Assessment	Impact assessment, which is divided into: Classification Characterization Valuation Improvement analysis

International Standards are playing a critically important role in all industries formational production, international terminologies, safety, and health protection, measurements, analysis, quality control, and environmental protection, particularly in the energy field, where standards for the interfaces in energy flows are indispensable, such as electric connectors, fuelling devices, calibration methods, and electrical safety. Besides the specific standards for petroleum, coal, nuclear and hydro-power, hydrogen and the vast field of electricity, the energy standards series ISO 13600 allows the characterization, analysis and comparison of all energy systems and soon will issue a global energy statistics and planning matrix for the transition to environmentally sound sustainable economics. These standards allow integrated resource planning, including all new renewable options, such as the increasingly important direct and indirect solar energy, co-generation, hybrid systems, small decentralized units, bio-energy, ambient temperature use by heat pumps and substitutions of muscle-powered systems or vice versa, besides the more efficient production and use of conventional finite and renewable energy-sources (Grob, 2003). The total cost of their emissions, their net gray, i.e. re-usable embedded energy, can be determined, total and relative efficiencies can be calculated and their life cycles and risks can be assessed with this new standard tool in conjunction with the many existing and emerging standards on specific energy systems or parts thereof (Figure 3.1).

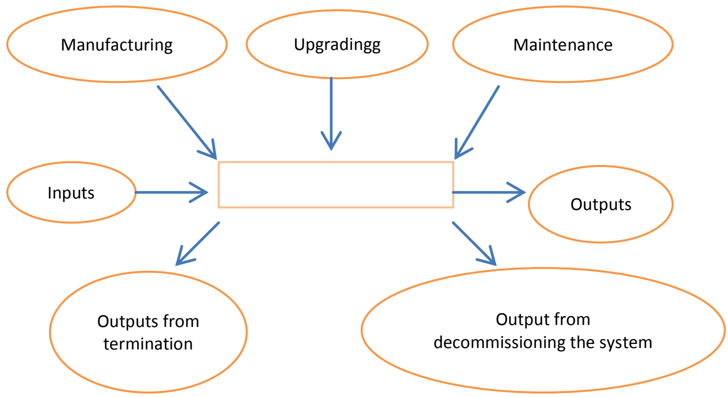

Figure 3.1 *Factors affecting the total cost of emissions (adapted from Grob, 2003).*

LCA is a process:

To evaluate environmental burdens related to products, processes or activities, to identify potential impacts on the environment coming from energy or material consumptions, to identify and to evaluate possible product improvements (SETAC, 1993).

3.3 General Analysis

The 'from cradle to grave' perspective, which LCA can take into account, makes it possible to judge and improve environmental performances over the entire life cycle, as well as appraise embodied improvements at particular levels. Nevertheless, depending on the specific requirements of a company, LCA may also be used in a limited perspective ('from process to process'), which can be of particular interest should the company wish to analyse carefully a limited part of the whole life cycle, the one under its own control (De Monte *et al*., 2005).

As regards the potential applications of LCA, Azapagic (1999) from Hospido *et al*. (2003) put forward the main uses as follows:

- Identification of environmental improvement opportunities.
- Strategic planning or environmental strategy development.
- Product and process optimization, design and innovation.
- Environmental reporting and marketing.

Life cycle assessment (LCA) is an analytical tool for the systematic evaluation of the environmental aspects of a product or service system through all stages of its lifecycle. A graphical description of LCA methodology based on the principles of ISO 14040 is shown in Figure 3.2.

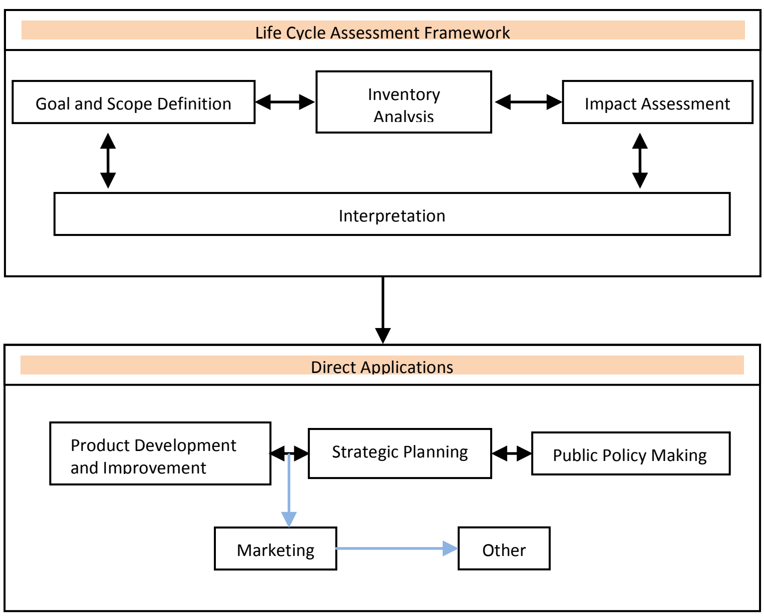

Figure 3.2 *Phases and applications of an LCA (ISO 14040, 1997).*

The main applications of LCA are in:

- Analysing the origin of problems related to a particular product,
- Comparing improvement variants of a given product,

- Designing new products,
- Choosing among a number of comparable products (LCA part 1).

Pennington *et al*. (2004) recently compiled a review on the life cycle impact assessment (LCIA) phase, focusing on the key attributes of the supporting models and methodologies.

These models and methodologies provide LCA practitioners with the factors they need for calculating and cross-comparing indicators of the potential impact contributions associated with the wastes, the emissions and the resources consumed that are attributable to the provision of the product in a study. ISO 14042, entitled 'Life Cycle Assessment – Impact Assessment (LCIA)', proposes to provide guidance on the impact assessment phase of LCA. This phase of LCA is aimed at evaluating the significance of potential environmental impacts using the results of the life cycle inventory analysis (Haklik, 1998). The environmental load unit taken from the natural resource or substance effect index multiplied by the amount of the substance used or released produces total environmental load value (ELV) for the particular product or process (Kuhre, 1995). Because of the inherent subjectivity in impact assessments, the most critical requirement for their conduct will be disclosure, so that decisions and assumptions can be clearly described and reported (Haklik, 1998). LCA consists of both mandatory and optional elements, as illustrated in Figure 3.2 (ISO 14042, 2000):

- Selection of the impact categories of interest, the indicators per impact category, and the underlying models (a procedure also considered in the initial goal and scope phase of an LCA).

- Assignment of the inventory data to respective impact category. Impact categories include climate change, stratospheric ozone depletion, photo-oxidant formation (smog), eutrophication, acidification, water use, and noise.

The food production industry requires large inputs of resources and causes several negative environmental effects. The food production systems are oriented and optimized to satisfy economic demands and the nutritional needs of a rapidly growing world population. Environmental issues, however, have not been given much attention. There are many difficulties in conducting life cycle studies of food products. Ideally, a complete study should include agricultural production, industrial refining, storage and distribution, packaging, consumption and waste management, all of which together comprise a large and complex system (Koroneos *et al.*, 2005).

LCA Studies on Foods

Table 3.2 *LCA Studies on Foods; Source: I. S. Arvanitoyannis 2008.*

Product (Food)	Country	Effects	Reference
Peas, bread and milk product	The Netherlands	Environmental impacts from packaging in proportion to other parts of the supply system	Kooijman, 1993
Margarine	The Netherlands	Two margarines and two low-fat products were investigated, concentrating on the fat components and packaging	*Vis et al.*, 1992
Bread and Meat	Denmark	Qualitative study with a very broad definition of environmental parameters	Pederson, 1992
Canned cooked Products	Austria	Application of the Institute for Okologische Wirtschaftsforschung's eco-balance system. The study involved four canning industries and one producer of packaging	IOW Wien, 1992
Fruit Yogurt	Germany	Comparison of processed products from ordinary and ecological agriculture	Ott, 1992
Bread, beer and Cheese	Germany	Comparison of processed products from ordinary and ecological agriculture	Ott, 1992
Tomatoes and Cucumbers	Switzerland	Comparison of seven hydroponic systems and eight ordinary production systems (under glass, In tunnels, and outdoor production)	Hahn, 1992
Tomatoes	Switzerland	Comparison of seven different ways of producing Tomatoes under glass	Cysi and Reist, 1990
Potatoes	Switzerland	Investigation of seven combinations of thermal, mechanical and chemical potato topping	Jolliet, 1993
Milk Chain	Sweden	The total use of energy and packaging materials seems to be	Sonesson

Product (Food)	Country	Effects	Reference
Supply		crucial to the outcome. More knowledge of the amount of wastage in households is required, both in absolute numbers and as influenced by the type of packaging	and Berlin, 2003
Ketchup Production	Sweden	Six alternative sub-systems, including packaging, processing, and transportation, were modelled and simulated. The environmental impact categories included were energy use, global warming, acidification, eutrophication, photo-oxidant formation, and the generation of radioactive waste. It was concluded that the contribution to acidification can be reduced significantly and the environmental profile of the product can be improved for either the type of tomato paste currently used or a less concentrated tomato paste	Anderson and Ohlsson, 1999
Milk Production	Spain	Different sub-systems were identified and thoroughly studied – farms, fodder factories, and dairies – and even through the collection of their inventory data took place throughout one complete year, some values were found to vary considerably. Raw milk production, specifically the agricultural phase, and packaging manufacture have been identified as the crucial elements. Other aspects such as formulation of animal food at farms and emission from boilers at dairies are also decisive when improvement actions are to be set up	Hospido *et al.*, 2003
Beer	Greece	The impact categories most affected by the beer Production are the earth toxicity or heavy metals and the Category of smog formation. Bottle production, followed by packaging and beer production are found to be the sub-systems that account for most of the emissions	Koroneos et al., 2005
Wild caught And farmed Salmon	Norway	The fishing phase for the cod and the feeding phase for both salmon and chicken dominate for all Environmental impacts considered. Chicken is most energy effective followed by salmon and cod, which are almost on the trawling is around 100 times larger than the land area needed to produce the chicken feed for production of the 0.2kg fillet. There is potential for improvement of environmental performance, both for salmon farming and cod fishing, especially when it comes to energy use	Ellingsen and Aanondsen, 2006
Danish fish Products	Denmark	Energy consumption is a key factor contributing to the environmental burden for all investigated fish products. The (quantitative) LCA suggests that the environmental hotspot for flatfish is the fishing stage. The same applies to cod, Norway lobster, shrimp, and prawn. Generally, however, the use and retail stages are also important, while the processing stage only represents an important impact potential for certain types of fish products (pickled herring, canned mackerel and mussels)	Thrane, 2006
Fish	The Netherlands	Impacts such as climate change, stratospheric ozone depletion, photo-oxidant formation (smog), eutrophication, acidification, toxicological stress on human health and ecosystems, the depletion of resources and noise. The need exists to address these product-related contributions more holistically and in an integrated manner, providing complementary insights to those of regulatory/process-oriented methodologies	Pennington *et al.*, 2004
Canned Tuna	Spain	The system under study included landing at harbour, Transport to the factory, processing inside the factory, Final product distribution to markets and use in households. The results show that processing accounted for the greatest percentage in all the	Hospido *et al.*, 2006

Product (Food)	Country	Effects	Reference
		impact categories, except human toxicity potential. Inside the factory, the production and transportation of tinplate was identified as the most significant contributor and, consequently, improvement actions were proposed and evaluated, such as an increase in the percentage of the recycled tinplate	

3.4 Actualisation: LCA Case Studies Reported – Dairy Processing

The dairy sector has been extensively studied from the perspective of LCA in Norway: milk production (Hogaas, 2002); Sweden: milk production focused on the farm level (Cederberg and Mattson, 2000) and semi-hard cheese (Berlin, 2002); and Germany: milk production, with a special interest on impacts associated to agriculture (Cederberg and Mattson, 2000; Haas *et al*., 2001). Although all dairy products are essential for the everyday nutritional regime, milk production has been chosen in this work as the most representative due to its outstanding position as an important staple food. In fact, most citizens consider consumption of milk in infancy, childhood and throughout adult life, as a prescription for good health. Regarding the different types of milk, skimmed milk (0.5% fat), semi-skimmed milk (1.5–1.8% fat) and whole milk (3.5% fat) are the most important ones (Hospido *et al*., 2003). The life cycle of milk production included in the analysis by Hospido *et al*. is shown in Figure 3.4.

In this analysis, six categories have been considered (global warming, stratospheric ozone depletion, acidification, eutrophication, photo-oxidant formation, and depletion of abiotic resources) as well as a flow indicator, energy consumption; on the contrary, others such as eco- and human toxicity and land use were not analysed. In a qualitative way, they considered that potential damage over those categories should not be very significant if the nature of emissions (with the exception of pesticides at the agricultural phase) and the

Galician land characteristics (low population density and low industrial character) are borne in mind. Among these six categories, three have been reported as significant: eutrophication, acidification, and global warming. Several actions focused on these categories (specifically on eutrophication potential (EP) and acidification potential (AP)) have been proposed and the percentages of reduction have been measured. However, it is necessary to indicate that there is an action that, although it cannot be quantified, had to be pointed out due to its importance on global warming potential (GWP). Methane emitted by cows on farms is responsible for more than 30% of greenhouse gas emissions, so it has an outstanding weight. The elements involved at animal feed turned out to be accountable for an important percentage of all the impact categories at the farm level. In addition, the item 'impacts associated with milk production', which includes emissions to air as well as to water, were identified as responsible for certain categories (GWP and PCOP). The milk supply chain model consists of two main parts: a background and a foreground system (Figure 3.4). The actual handling of dairy products is the foreground system. However, to supply the foreground system with such necessary inflows as packaging material, water, and energy in various forms, and also to take care of its residues, background systems are necessary. The results from a simulation thus include emissions from both background and foreground systems as well as all use of primary energy carriers caused by the milk supply chain. All models are static, i.e. the emissions and use of energy change linearly with changes in the flow, no economies of scale are assumed.

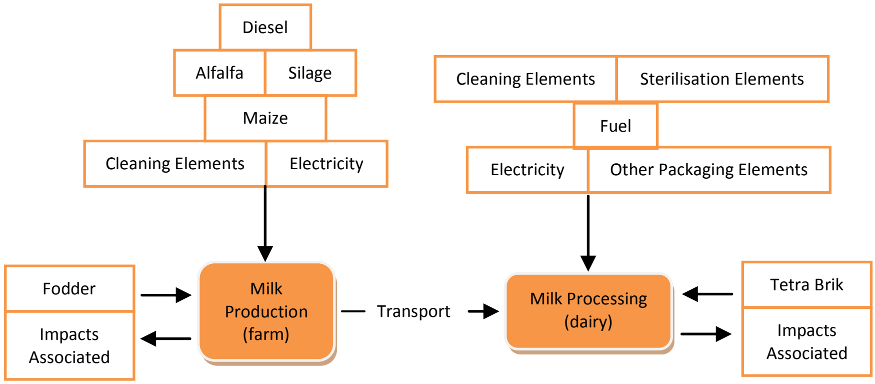

Figure 3.3 *Schematic flow chart of the life cycle of milk. (adapted from Hospido et al., 2003).*

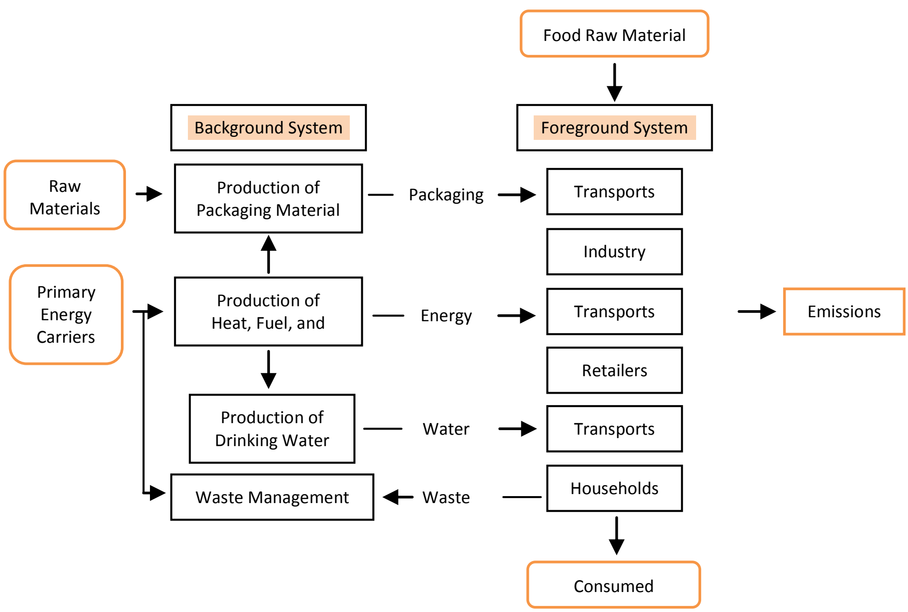

Figure 3.4 *LCA in future milk supply chains in Sweden (adapted from Sonesson and Berlin, 2003).*

The subsystems involved are as follows:

- Truck transport.
- Car and van transport.

- Dairies.
- Retail.
- Households.
- Energy system.
- Production of packaging material.
- Production of drinking water.
- Waste management (Sonesson and Berlin, 2003).

Within dairies, more products and more frequent deliveries to retailers probably result in less efficient dairies. The effects are also noticeable in distribution, retailing, home transport, and wastage within households. The model used in this study could still be improved to reflect fully the strong trends in this direction and provide reliable indications of their effects on environmental impacts. The total use of energy and packaging materials seems to be crucial to the outcome. More knowledge of the amount of wastage in households is needed, both in absolute numbers and as influenced by the type of packaging. In future studies, it might be interesting to include agriculture in the analysis since different future scenarios will probably also affect the structure of agriculture. In this study, agricultural patterns would probably differ in the large-scale scenario and in the green IT-wave scenario and thus would have different impacts on the environment.

3.5 Discussion

Nowadays, there is an increasing awareness that today's life style should aim at more sustainable production schemes in conjunction with limited use of renewable resources and minimal environmental impact on land, water and air

(Environment inhttp://www.tc207.org/articles/). All processes have to be envisaged as potential resources since their by-products provide the primary material for a subsequent process in a continuous regenerative loop (Tansey and Worsley, 1995). Life cycle assessment, though not a brand new tool any more, is still able to analyse and assess the environmental impacts associated with a product, process or service by multi attribute product evaluations. The importance of LCA as an environmental decision support tool continues to increase rapidly. A distinction between the objective and subjective elements of LCA is bound to take place in order to clarify the structure of the method and be of great help to the decision-making. Goal definition and scoping as well as interpretation of the inventory results would benefit most from decision analytic approach and methods. In these phases, subjectivity and the overall goal of the process have a major impact. The important dimensions of the decision problem could be presented in a value tree and this could be exposed to general discussion and modification before deciding the actual content and scope of the study. Pertinent answering of the prioritization questions at an early stage of the study is anticipated to help greatly the decision-makers in terms of identifying both the real decision alternatives and the concrete environmental problems closely linked with the product's environmental impacts thus providing the required inventory data. Valuation referring to values is another subjective issue and is closely linked to preference data (Miettinenand Hamalainen, 1997).

3.6 General Recommendations

3.6.1 Waste Management

What is being recommended is that multi-station sampling points from different unit operations gather composite samples of representative flows discharged per shift in food processing areas for analytical purposes. These samples need to be tested for COD or BOD, plus those components specific to the foodstuff being processed. If we assume the raw material produced into a food contains carbohydrate, fat, proteins, and minerals besides water, then the different components have variable values depending on the ingredient source at the sampling station. Obviously, raw material components would be less valuable than components lost in products at other stages prior to the finished good value. For example, product X might be worth 20 cents/kilogram as raw product when the worth of components with carbohydrates is 5 cents/kilogram, 15 cents/kilogram for the protein fraction and 10 cents/kilogram for fat content. Further up-line in processing, when product is cooled and concentrated, the protein, and fat content are increased. In fact, the kilogram value might double to 30 cents for protein and 20 cents for fat losses with little change in carbohydrate value. When product loss occurs at this step more loss value needs to be applied to components sent to floor drains. This kind of an evaluation process quickly shows that affirm needs to begin paying strict attention at key steps to maximize product yield. All losses are vital, but we are perfectly safe in thinking more money will be lost in finished goods or partially finished products than for raw material in a food processing sequential step operation. Here are the things that need to be done:

- Establish a loss sampling station.
- Gather and test representative samples of loss materials sent to drains.
- Assign dollar values to different components.
- Provide unit operation supervisors loss information promptly so corrective actions might be taken to improve operations. On the other hand, the data

may well confirm to people that the operation is being carried on with success. This too is vital for people to know.

- Inventory wastage with the same vigour you would do for other items in your shift or day accounting system.

3.6.2 Life Cycle Assessment

Reporting the results of LCA must be impartial and complete. Objective reporting is made to third party; the requirements of the standard should cover at least the following aspects:

- general aspects;
- defining the purpose and scope;
- life cycle inventory analysis;
- life cycle impact assessment;
- life cycle interpretation;
- Critical analysis.

Critical analysis is essential and it can be made by an independent internal expert LCA study or by an external expert analysis that will give an analysis statement. SR EN ISO 14041 standard - Definition of the purpose, scope and inventory analysis – establishes requirements and procedures for setting up and training the purpose and scope definition for a Life Cycle Assessment (LCA) and for the development, interpretation and reporting cycle inventory analysis Life (ICV). The product-system is detailed here and the final product is indicated next to intermediates, auxiliary inputs, uncontrolled emissions, data quality, sensitivity analysis, uncertainty analysis, etc. For Life Cycle Inventory analysis, the “system product” which is composed of “units of product” must be defined more clearly.

It is essential that function, functional unit and reference flow to be clearly defined and to determine the boundaries of the original system. Inventory Analysis is made according to the logical scheme of Figure 3.5.

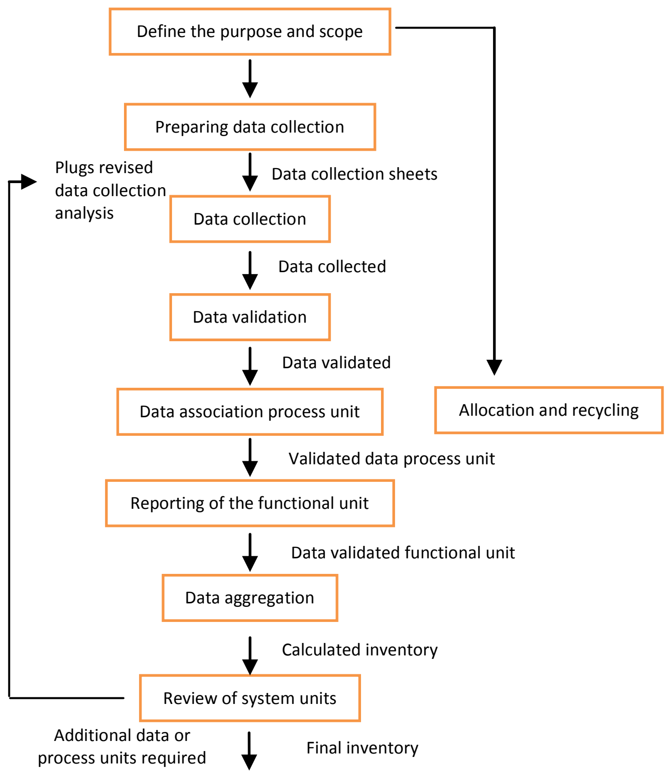

Figure 3.5 *Simplified procedures for the analysis of inventory.*

3.7 Conclusion

Integration of companies from various parts of the world in production and distribution of ordinary products (salad, fruit, etc..) is a globalized phenomenon. Of course, transportation is no longer a problem, technology on a bed of closed-circuit water, organic loading is widely controlled. Disputes of GM food technology have social implications in employment in overcrowded areas. To gain access to these disputes the only way is to implement LCA management systems. So we have the technical data and even the possibility of participating in the dialogue provided by the policy in the field.

In recent years there has been accumulated large volume of communications on Custodies, and almost each of them claims fairness. To speak a common language we should relate strictly to the implementation of the reference standards SR EN ISO14040 series and procedures and records required by them. It is good to make implementation a consultant may, by Curriculum Vitae, evidence that leads directly to people and businesses. Vision is needed for overall management, linking the action system - product assembly and parts (sub-systems) components. LCA requires that analysis be made by independent experts, preferably external, to ensure objectivity. Objectivity ensures correct conclusions that will lead to finding that waiver decisions on economic and environmental grounds, a number of other systems - a product which actually represents the chain of companies and business, technical facilities, capital and workers with families and local communities. There are no acknowledged and accredited certification bodies of referential standards SR EN ISO 14040 series, still their application can solve the problem out – by developing a dialogue between stakeholders and consulting firms, creating regional accreditation bodies for our benefit.

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