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LIFE CYCLE ASSESSMENT: MANAGEMENT TOOL FOR DECISION-MAKING

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ABSTRACT

Given societal awareness that usage of manufactured goods and services adversely impacts the supply of natural resources and the environment, the consumer market began to firmly question the developmentalist economic model typically used by enterprises in the 1970s. Questions emerged regarding its validity as a definitive solution in the quest to satisfy consumer demand. In this scenario, many corporations found themselves forced to make changes to their environmental policies in order to reduce the negative impacts of their activities. Due to this societal pressure, company actions aimed to guarantee market share, rather than broaden the scope of business activities. Initially, only reactive environmental control measures were adopted, aiming solely to reduce adverse environmental effects caused by humankind. In realizing that this approach would not legitimately guarantee Sustainable Development, modern society began to pursue new and more auspicious practices, this time more pro-active in their nature, to reach or at least address, the conditions posed by this paradigm. This notion prompted the emergence of concepts such Environmental Management and Pollution Prevention along with concepts, techniques, and methodological procedures conducive to an appropriate modern environmental stance for the current reality. The technique of Life Cycle Assessment – LCA must be underscored in the context of the broad nature of the approach, systematic in its essence, and the deepening degree of interactions between human systems and the environment. The objective of this paper is to discuss the intrinsic elements, technical content, applications and limitations of the LCA, as well as its application in Environmental Management and Pollution Prevention scenarios.

Key words: Life Cycle Assessment; LCA; Environmental Management; Pollution Prevention; Environment

INTRODUCTION

Society's stance regarding the importance of preserving the environment has impacted the activities of productive sectors in this regard over the last four decades. In the early 1960s, newfound societal awareness that consumption of manufactured goods and services were adversely impacting the supply of natural resources and the environment, the consumer market began to firmly question the developmentalist model and its validity as a definitive solution in the quest to satisfy the modern man's consumer demands.

For this reason, the business community was obliged to make successive alterations to its conduct with regard to reducing the adverse environmental impacts caused by its activities; these actions aimed primarily to guarantee market share, rather than garnering new market niches.

In the first phase, as was characteristic of the 1970s, companies opted to take a reactive stance to environmental issues, implementing environmental control measures. This phase was marked by the action of the State, which took on the role of inspector, regulating the activities of organizations to limit their environmental impact.

The notion that preserving the environment could reduce operating expenditures led corporations to an evolution in their management policies. In this manner, by the second half of the 1980s, one witnessed a shift to a pro-active stance against environmental issues, characterized by the implementation of prevention measures. In other words, instead of treating industrial waste solely to comply with legal standards, industries began to focus on reducing waste or finding different ways to reuse waste to lessen environmental impacts. This perspective created a particularly advantageous scenario for implementation of techniques, such as Environmental Impact Studies, Environmental Management Systems, Pollution Prevention Programs, Environmental Risk Assessments, among other.

The perception that the use of control and prevention actions in the productive chain of a given product was necessary, but not enough to perpetuate sustainable development, induced a reorientation in the manner in which environmental programs should be conducted, fundamentally in post-production phases. In this scenario, Life Cycle Assessment (LCA) emerged as a systemic tool with a view to filling this void, as well as aiding in the decision-making process for administrators.

Given these considerations, the objective of this paper is to present the importance of the above-mentioned methodology in the context of environmental management and pollution prevention.

LIFE CYCLE ASSESSMENT

The implementation of control and prevention measures has constituted a decisive factor for an increase in the environmental performance of organizations, and as a result by bi-reciprocal correlation, improved environmental conditions for the planet manifested in the form of a deceleration in the degradation thereof.

Nevertheless, these actions are usually referred to as *focus on the process* due to the fact that their approach normally only ponders the limits of an organization's battery of individual units. (SILVA, 2003)

Society's reflection on this preventative stance raised consciousness of aspects pertaining to sustainable development. Material and energetic waste are generated from the consumption and transformation of natural resources into goods and services. Therefore, preventing waste does not mean solely reducing pollution levels – defined as emptying waste generated by humankind into the environment – but also minimizing material and energetic resource use. Furthermore, if one considers that waste treatment and disposal implies costs for any organization, reducing losses in the productive process translates into savings, which, from the point of view of economic balance, could be understood as increasing profit.

The evolution of this line of thought became, however, increasingly more evident, to the extent that even the preventative approach to environmental issues lacked an ample framework to meet to society's needs regarding sustainable development. This was so much so that the globalization phenomenon has called for an approach that can effectively broaden the focus beyond the limits of each organization's units. This is perhaps the origin of "Life Cycle Thinking" (LCT) (SONNEMAN, 2002).

According to Sonneman (ibid.), LCT can be understood as the awareness that the good environmental performance of an isolated productive chain is not sufficient to guarantee the sustainability thereof; this condition can only be attained if all links in this chain present appropriate environmental performance. In this context, emphasizing that the assessment of a product, process or service's environmental performance is not solely based on waste disposal, but also consumption of natural resources, is never excessive.

Silva and Kulay (2003) proclaimed that the LCT, as an evaluation of environmental performance, should be conducted systemically, covering all activities involved in manufacturing a product that can potentially impact the environment. Therefore, all these activities throughout the productive chain, from the attainment of natural resources to manufacture of the product, are subject to this approach. This scope of application is denominated as *focus on the product*.

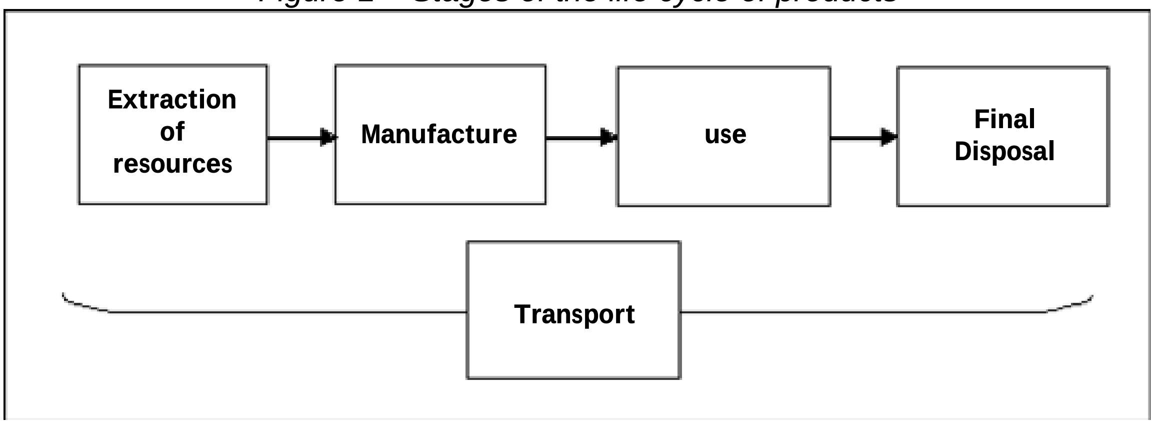
Critical observation of production models leads one to determine that the manufacture of any product is not in itself an end, but a means to meet the society's necessities or desires; or rather, products are manufactured to perform a function. This implies that its potential impact on the environment is exhausted at the end of the productive chain. On the contrary: the path to fulfillment of its function; the activity in itself; its destination after its function is exhausted – its final disposal in the environment, or recycling – are activities that could equally impose significant environmental impacts.

An assessment of the environmental burden resulting from the satisfaction of a certain human need via the manufacture of a product will be discerning and consistent only if all stages of the life cycle of this good are considered; this is obtained through application of a *focus on the exercise of the product function* analysis approach (SILVA, 2003).

As such, the *life cycle* concept can be understood as a set of necessary steps for a product to perform its function, including the attainment of natural resources and its final disposal, soon after it has exhausted its function. Therefore, activities like manufacture, distribution, usage, and the post-usage recycling of the product are considered within this spectrum (VIGON, 1993).

Figure 1 presents the five stages that generally constitute the life cycle of any product.

Figure 1 – Stages of the life cycle of products



Source: Adapted from Fava (1991).

Observation: Transport is considered a stage of the life cycle because it is an activity that can potentially impact the environment and permeates practically the entire life cycle of products.

LIFE CYCLE ASSESSMENT CONCEPT

With the life cycle concept consolidated, it is possible to conceptualize the Life Cycle Assessment (LCA) as a technique to evaluate the environmental performance of a product throughout its life cycle. This assessment is conducted both by identifying all interactions occurring during the life cycle of product and environment, as well as by the evaluation of the environmental impacts potentially associated with these interactions. (CURRAN, 1996)

BRIEF HISTORY OF THE LIFE CYCLE ASSESSMENT

The first analyses focused on the environmental question date back to the mid-1960s, when many large corporations, preoccupied with reducing their operating costs, decided to conduct an inventory of energy costs pertaining to the manufacture of their products.

One of the most notable examples of this group of initiatives is the study conducted by Franklin & Associates in 1969 at the request of Coca-Cola Co. The study included consumption of raw materials and energy in the manufacturing processes for packaging used for company products. (FABI et al., 2004).

The compilation of works conducted with this focus, known at the time Resource Environmental Profile Analysis (Repa), years later provided the necessary theoretical basis for the conceptualization of LCA.

The Repa reports played an important role during the first oil crisis. This is because, as Christiansen (1996) notes, at the request of the governments of several industrialized nations between the years 1973 and 1975 detailed studies were conducted assessing the planet's energetic potential, including not only a situational analysis of the problem, but also alternative proposals to the use of fossil fuels.

The great diversity of standards and criteria for application of the methodology, coupled with the lack of a broad and reliable data base and the elevated costs involved in producing such studies, resulted, however in the manipulation of the results obtained in many cases. For this reason, this type of study ended up being discredited in the scientific community, which was followed by its consequent, albeit temporary, abandonment thereof.

The certainty that usage of a *focus on the exercise of the product function* approach would be the best manner to evaluate the interaction between a product and the environment throughout its life cycle led many research centers to continue investing time and resources to perfect deficient aspects of the technique in order to make it an executable and reliable procedure. The LCA is the result of the progress of these efforts.

Although the Life Cycle Assessment is still in the final phases of evolution in terms of some of its parts, interest in the method has increased for its varied uses. Within the institutions dedicated to perfecting and divulging this methodology, the Society of Environmental Toxicology and Chemistry (Setac) deserves special attention for the role it has played. In the opinion of many users, this institution – which for over a decade has concentrated its efforts on consolidating a uniform and consistent conceptual base - currently constitutes the most respected forum for discussion on many aspects correlated to the methodology worldwide.

As a result of the LCA's importance in the context of Environmental Management and Pollution Prevention, the structural methodology that it constitutes was standardized by the International Organization for Standardization (ISO), respectively as 14040 of the ISO 14000 series. The following technical norms in this collection had been launched by 2005:

- ISO 14040: Environmental management – Life Cycle Assessment – Principles and framework (1997)
- ISO 14041: Environmental management – Life Cycle Assessment - Goal and scope definition and inventory analysis (1998)
- ISO 14042: Environmental management – Life Cycle Assessment – Life cycle impact assessment (2000)
- ISO 14043: Environmental management – Life Cycle Assessment – Life cycle interpretation (2000)

More recently, in 2002, the Life Cycle Initiative (LCI) was created through a partnership between the United Nations Environmental Program (UNEP) and Setac. Among its many objectives, the LCI aims to use the LCA in three global programs. The first of these programs is called Life Cycle Inventory and is dedicated to the development of methodology to produce environmental inventories (REBITZER, et al., 2004).

The second program established by the LCI, so-called Life Cycle Impact Assessment, is dedicated to consolidating the Impact Assessment stage that is part of almost all LCA studies. The trilogy is completed by the Life Cycle Management program which aims to stimulate the aggregation of a life cycle perspective to all actions inherent to business management with a view to obtaining increased environmental efficiency for products and services.

Trajectory of the LCA in Brazil

The history of the LCA in Brazil began in 1993 with the creation of the Standardization Support Group (Grupo de Apoio à Normalização - GANA), a subcommittee dedicated specifically to the theme under the coordination of Hubmaier Andrade, Cícero Dias , and José Ribamar Chehebe, three environmentalists that had ties both with academia as well as the business world. In the last five years these efforts have begun to bear fruit. The first specialized publication on the matter was *Analysis of the Life Cycle of Products: ISO 14000 Management Tools* (*Análise de Ciclo de Vida de Produtos: Ferramenta Gerencial da ISO 14000),* which was written by José Ribamar Chehebe (1997).

The year of 1998 witnessed another milestone for the LCA in Brazil with the emergence of the Pollution Prevention Group (Grupo de Prevenção da Poluição - GP2), from the São Paulo University’s Polytechnic School (Escola Politécnica da Universidade de São Paulo). Created with the objective of generating knowledge and developing competencies in the fields of pollution prevention and environmental management, the GP2 decided to make studying LCA its main line of research. This research, which is conducted by Professor Gil Anderi da Silva, has become an intellectual production that by the second half of 2005 had spawned six master’s dissertations, one doctoral thesis, and more than forty articles in periodicals and congressional records both nationally and internationally (KULAY, 2004).

In the second half of 1998, Gana ended its activities and was substituted by the Brazilian Environmental Management Committee, known as CB-38, of the Brazilian Technical Norms Association (Associação Brasileira de Normas Técnicas - ABNT). Due to this fact, this entity also began to manage LCA projects, now under the superintendence of Dr. Haroldo Mattos de Lemos. In general terms, the CB-38 is dedicated to organizing Brazil’s contribution – manifested in the form of suggestions and investments from institutions of the most diverse levels and segments – to formulate norms for the ISO 14000 series linked to environmental management, environmental inspection, environmental labeling, environmental performance assessment, life cycle assessment, and terminology.

Operating with a structure similar to that of the ISO TC207, the CB-38 has a permanent forum for discussions on Brazilians standards for Life Cycle Assessment under its subcommittee SC-05. This subcommittee's first product dates back to 2001 with the nationwide launch of the "NBR ISO 14040: Environmental Management –Life Cycle Assessment – Principles and Structure (NBR ISO 14040: Gestão Ambiental – Avaliação do ciclo de vida – Princípios e estrutura) standard. Recently in 2005, it also released the NBR ISO 14041: Environmental Management –Life Cycle Assessment Definition of Goals and Scope and Inventory Analysis (NBR ISO 14041: Gestão Ambiental – Avaliação do ciclo de vida – Definição de objetivos e escopo e Análise de Inventário).

The newest of work fronts for diffusion of the LCA was established in 2002 with the creation of the Brazilian Life Cycle Association (Associação Brasileira de Ciclo de Vida – ABCV). Open to manifestations from diverse segments of society, this institution's mission is build a national data base for LCA studies and promote capacity-building for a critical mass of individuals to put LCA into practice and maintain ties with the international community involved with the theme (KULAY, 2004).

The decision to create the ABCV began with discussion within the business sector, academia and the government to gauge investments for diffusion of LCA in Brazil. Although budgeted at lofty values, the consensus among founders of the entity was and continues to be that any outlays aimed at making LCA a well-known, reliable, and consistent technique will afford greater comprehension and planning of production systems and procedures, thus promoting an increase in productivity and guaranteeing that Brazilian companies will obtain environmental certification and seals that will ensure the entry of their products into the markets of industrialized nations.

The Brazilian LCA Project

To undertake the initiatives it has proposed, the ABCV has decided to develop the Brazilian LCA Project (Projeto Brasileiro de ACV) which is centered on two programs:

training in LCA competencies and building up the Brazilian Data Base for LCA studies conducted in and for the country (KULAY, 2004).

The LCA competency training program is in the most general sense the implementation of diverse actions in higher education (graduate and post-graduate degrees), for which it will propose the inclusion of the Life Cycle Thinking approach into the curriculums of pertinent disciplines.

In reference to specific training of LCA specialists and users, plans include:

• fostering the constant development of the LCA in post-graduate programs with the objective of training specialists that will, in turn, act as multipliers in the diffusion of this knowledge;

• creating specific disciplines based on LCA in professionalization courses;

• stimulating the participation of academic and non-academic professionals in short and medium duration training programs outside Brazil.

The Brazilian Data Base to aid in the development of LCA studies should, for its part, be conceived to safeguard aspects of transparency and consistency. Furthermore, operationally the framework and format should allow for the incorporation of any computer program to support LCA studies (SILVA, 2003).

For these objectives to be reached, this part of the program was structured according to the following phases of execution:

Preparatory Stage

• Identifying people and companies in Brazil that are in any way interested in the LCA in order to establish training levels.

• Holding a workshop in conjunction with international entities linked LCA – like como Setac, Life Cycle Initiative, Unep, developers of data bases and specialized computer programs for LCA – to subsidize the definition of parameters and criteria to be used in building a national data base.

• Development of a sub-project for operating the data bases.

Execution of Inventories

- Execution of inventories according to standards established during the workshop.

Dissemination of results

- Communication of results.
- Incorporation of data bases generated by computer programs to support LCA.

Maintenance

- Developing complementary inventories.
- Updating existing inventories.

In terms of the evolution of the project, to date the entity has undertaken the identification process for Brazilian LCA competencies, besides holding two workshops with international specialists with a view to establishing rules to delimit the Brazilian inventory (SILVA, 2003).

Simultaneously, a partnership is already underway between the ABCV, the Brazilian Institute of Information in Technology (Brasileiro de Informação em Tecnologia - Ibict) linked to the Science and Technology Ministry (MCT) and the Swiss government via Empa, a research center dedicated exclusively to environmental matters. This initiative aims to give Brazilian technicians a unique opportunity, and why not add, for concrete absorption of Switzerland’s training on the development of data bases (KULAY, 2004).

USAGE AND APPLICATIONS

For an assessment methodology in which a focus on the product function approach is used, the LCA provides information on the interactions that occur between the stages of the life cycle of a specific good and the environment. For this reason, one of the first symposiums organized by Setac in the first half of the 1990s, whose mission was discussing the future of LCA, established that a study of this nature is based on the following premises:

- providing an accurate image of any and all existing interactions with the environment;
- contributing to global and interdependent knowledge of the environmental consequences of human activities;
- generating subsidies to define the environmental effects of human activities; and
- identifying opportunities for improvements in environmental performance.

For this reason, it is possible to separate applications for the LCA into two major areas:

- identification of opportunities to improve environmental performance; and
- an environmental comparison of products that perform equivalent functions.

In the first area, the LCA acts to ascertain the main foci of environmental impacts caused by a product system. At the end of its application, the user will have established the product system's contribution to the diverse categories of environmental impact. With diagnosis in hand, action plans to minimize these impacts can be devised.

Usage of the LCA for this purpose is illustrated by a joint study conducted by researchers for telecommunications multinationals NTT and NEC in 2002 (TAKAHASHI et al, 2003). The study in question involved application of the LCA for the development an environmental diagnosis of equipment and facilities that comprise the cable information and communication network in Japan.

In applying the LCA for comparison of different types of products - and their associated impacts – that perform the same function, environmental aspects are evaluated.

Utilization of the LCA with this bias has a large appeal to business organizations eager to show the environmental superiority of their products over their direct competitors as a means of conquering new markets.

Furthermore, when conducted comparing the environmental performance of one or more products against a pre-established standard, the ACV could serve to develop labels and environmental declarations.

The fact that the LCA constitutes an efficient technique to develop environmental diagnoses facilitates its application for the strategic activities of an organization, such as projects for new products and reassessment of existing products.

In these cases, the LCA is useful in the selection of project options, particularly regarding new materials, alternative forms of energy, and implementation of improvements to minimize losses and conception of products that are less aggressive to the environment. One example is a 2000 study conducted in Spain with two types of street lights for urban roadways (IRUSTA and NUNEZ, 2001).

In the case in question, the existing product – a streetlight encased in aluminum - was compared to another (encased in polyethylene), which at the time had been considered to substitute the former. The conclusions reached through the LCA established fundamental guidelines for a lighting project that would provoke lower environmental impacts throughout its life cycle.

The LCA is also useful to environmental agencies and even non-governmental organizations, especially in defining public policy aimed at structuring sustainable systems.

This initiative is exemplified in a 2002 study conducted by the Scottish Environment Protection Agency with the objective of defining national strategies manage solid residue. In the case in question, the LCA was used as a selection tool to choose the most appropriate waste management system among six prospective projects for each of the 11 locations slated to receive these investments, as described by Dryer and Ferguson (2003).

Jensen (1997) describes the LCA as a technical tool to facilitate major administrative decision-making via:

- identification of opportunities to improve environmental aspects of products in various stages of the life cycle;

- establishment of an array of information on the total resource use, energy consumption, and emissions;
- comparison of the system’s inputs and outputs regarding alternative products, processes, or activities;
- decision-making in industry, government and non-government organizations for development of sustainable products, processes or activities with regard to natural resources needs and waste generation;
- selection of pertinent indicators on environmental performance, including measurement techniques;
- marketing and improvement of products and services.

Finally, the LCA should soon gain importance for the competitiveness of companies, particularly export concerns, as well as a marketing profile due to release of the first version of the ISO 14025 standard this year. This instrument on product labeling involves a Type III Green Seal based on the good environmental performance of the product, which is determined by a LCA study. For this reason, one can deduce that environmental labeling could be used in the competitive processes to formalize commercial transactions on the international market.

TECHNICAL LIMITATIONS

Because it is a relatively new technique, the LCA still has certain operational limitations, among which is the high quantity of necessary data (UDO DE HAES and ROOIJEN, 2005).

In many cases, the process of data collection is rendered impossible for several reasons, such as the disinterest on the part of companies or productive sectors, and the matter of confidentiality for data related to specific inputs or technologies.

Many corporations are also clearly reticent about drawing the attention of environmental agencies and non-governmental organizations to the environmental aspects of their production processes, fearing a variety of sanctions.

Furthermore, the lack of unified methodology for technical applications, constitutes a problem in interpreting the results obtained from studies of this nature. In addition to ISO, Setac and a few respected institutions in the field abroad have proposed structural concepts to conduct LCA studies.

Although the disparities between one method and another are not excessive, there are records of studies based on these methodologies for the same case which produced distinct results.

Among the LCA's complications is a complete lack of models to assess the local and regional environmental impacts in countries located in the Southern Hemisphere (UDO DE HAES and ROOIJEN, 2005).

To date, any analysis for the region is conducted using European and North American models that are based on the geographical, climatic, hydric and surface realities of those regions.

METHODOLOGICAL ASPECTS

Although there are diverse methodologies for application of LCA, the system that the ISO has standardized internationally under norm ISO 14040 is the by far the most widely used. According to ISCO (14040), the LCA is comprised of four stages:

- Definition of goals and scope;
- Inventory analysis

- Environmental impact assessment;
- Interpretation of results

All these stages are inter-related, demonstrating the interactive character of the methodology, as can be observed in Figure 2 by following the arrows. A brief description of each of the previously cited elements will be presented below to show, albeit in a superficial manner, the technical concepts that permeate LCA methodology.

Definition of goals and scope

In the definition of goals stage, the main reason for conducting the study is established, along with its span and target audience. In the definition of scope, on the other hand, the essential methodological aspects are considered for execution of the study, such as establishing parameters like function, functional units, and product reference flow, boundaries, criteria for environmental burden, as well as impact categories to be used in the Impact Assessment stage **(**ISO 14040, 1997). In defining the scope, it is important to consider geographical aspects, weather, and the technology of the product system – or rather, the space in which the methodology will be applied – in order refine the definition of boundaries and selection of data to be used in the inventory.

Simply, the ISO 14040 norm (1997) established that the minimum content for the scope of a LCA study should refer to three dimensions: where to begin and end the life cycle study (extension of the LCA), how many and which subsystems to include (the span of the LCA), and the study's level of detail (the depth of the LCA study).

In practice, establishment of system boundaries should be carefully undertaken, because it should take into consideration available financial resources and time; in short, there is a certain conflict between precision and practicality. Therefore, one must adopt procedures that make the study manageable, practical, and economical without forgetting the aspects that make the model credible (KEOLEIAN, 1994).

Figure 2- Methodological Structure of the LCA, according to ISO 14040

Goal and scope

Inventory Analysis

Impact Assessment

Interpretation

- Definition of purpose,

boundaries and

target audience;

- Establishment of limits

for LCA application:

-function

-functional unit

- reference flow

-data pre-requisites

- allocation criteria

- Data collection:

- natural resources
- intermediate resources
- products and subproducts

- data treatment

- Classification of environmental impacts

(= separation into categories of impact)

- Characterization of environmental aspects

(= use of equivalence factors)

- Standardization and weighting

- Identification of the main problems during the LCA's course
- Sensibility analysis
- Conclusions

Source: Chehebe (1997), adapted by Fukurozaki and Seo (2004)

Inventory Analysis

Inventory analysis is the second phase of the LCA methodology. This phase involves the collection and quantification of all variables (raw material, energy, transport, emissions, effluents, solid residue, among others) that are related to the life cycle of a product or activity.

The inventory consists of an interactive process, whose sequence of events involves checking procedures in order to ensure that the quality requisites established in the first phase are followed. For many authors, this phase is similar to a financial balance sheet, in which materials and energy use are considered instead of economic values. For this reason, total system inputs should be comparable to the total number of outputs (KEOLEIAN, 1994).

In practice, the inventory is a difficult and laborious task for a number of reasons, all of which linked directly or indirectly to data collection. In this manner, it is recommendable that the inventory analysis phase be organized according to the following activities (ISO 14040,1997):

- preparation of data collection, which consists of developing a diagram of the process flow involving the phases of raw material acquisition, manufacture process, use/maintenance and recycling/waste treatment;
- data collection
- definition and refinement of system boundaries;
- establishment of calculation procedures;
- allocation procedures.

The ISO 14,040 determines that the general scheme for the inventory should in principle be constituted by:

- presentation of the product system to be studied and the boundaries in terms of Life Cycle stages, process units, and system inputs and outputs;
- a basis of comparison between systems (in comparative studies);
- procedures for calculation and data collection, including the rules for product allocation and for energy use;
- necessary elements for the reader's accurate interpretation of inventory analysis results.

Impact Assessment

Represents both a qualitative and quantitative process used in understanding and assessing the magnitude and significance of environmental impacts, which is based on the results obtained in the inventory analysis, taking into consideration the effects that can be caused to the environment and public health. The levels of detail, choice of impacts to be assessed, and the methodology to be used, depend on the objective and scope of the study. The impact analysis converts the results of the inventory to a group of selected impacts, such as the greenhouse effect, mortality, destruction of the ozone, euthrophication, photochemical ozone formation, toxicity, and land use, among others.

According to the text of the ISO 14040 (1997), impact assessment is generally constituted by the following elements:

- *Selection and definition of categories* – where the environmental concerns and categories, and the indicators the study will use are identified. The categories should be defined based on scientific knowledge of environmental processes and mechanisms. As this is not always possible is some specific cases value-based judgment can substitute scientific knowledge.

- *Classification* – where the inventory data are classified and grouped into diverse pre-selected categories (global warming, destruction of the ozone layer, acidification, human toxicity, natural resource depletion, etc…). The appropriate attribution of environmental aspects to its categories of influence is an essential condition for the relevance and validity of impact analysis.

- *Characterization* – the transposition of environmental aspects into their corresponding impacts, through application of conversion indices denominated equivalence factors. When characterization is complete, the product's *Profile of Environmental Impacts* can be detailed and used to directly compare the potential impacts of the object under analysis

Although not compulsory, the Impact Assessment can also consider Standardization and Valuation procedures, which are destined to consolidation of the environmental burden profile into one index.

Impact assessment may not be necessary in all of the LCA's applications for products; nevertheless, it is useful for evaluating opportunities to better the system's environmental performance and in cases in which the same diagnostic is essential to decision-making. (KEOLEIAN, 1994; CHEHEBE, 1997).

Interpretation of results

This phase consists of identifying and analyzing the results obtained in the inventory or impact assessment phases of the LCA. The product of the interpretation of results could take the form of conclusions and recommendations to professionals that use the LCA as an instrument to aid in the decision-making process. The interpretation phase of an LCA consists of the three following stages (ISO 14040, 1997):

- Identification of the most significant environment questions based on the results of the inventory analysis or LCA;
- Assessment could include elements like integrity checking;
- Sensibility and consistency; conclusions, recommendations and reports on the significant environmental issues.

FINAL CONSIDERATIONS

The LCA has increasingly become an important Environmental Management tool, perhaps because it is the only in its class that allows for a systematic approach both in identifying opportunities for bettering the environmental performance of a product and its environmental comparison to products that perform the same function.

The analysis afforded by the LCA is highly structured, involves various environmental matters simultaneously, and is based on quantifiable systems, and is therefore an objective technique.

Despite the potential its represents for decision-makers, the LCA still has its limitations, which should be overcome in order to consolidate the methodology’s contribution to the planet’s sustainability.

There was a time in the mid-1980s that the LCA’s credibility was put in check due to the fact that comparative studies on the same products presented contradictory results. Despite the goodwill with which these studies were conducted, this situation was unnecessary.

Preoccupation in the LCA community prompted meticulous studies on the origin of these differences, which found that given the complexity of the methodology, the criteria adopted to define data collection procedures could significantly influence the final results.

Furthermore, the adoption of these data collection criteria is dictated principally by the objectives and scope of the study. Or rather, the definition of various procedures to be used in the execution of studies is still based on subjective criteria, and, as such, is subject to many inconsistencies.

The palliative solution used currently as means of overcoming this limitation is found in the ISO 14040 (1997) norm, which stipulates that an import requisite is total and absolute transparency in preparation of the study, which for its part, should explicitly and unequivocally contain all premises and hypotheses adopted throughout its execution.

In this sense, another intellectual investment is necessary regarding the development and the consolidation of methodology for execution of LCA studies to make attainment of consistent and reproducible results feasible without compromising the obtainment of the numerous and distinct objectives thereof.

Another obstacle that hinders greater diffusion of the LCA is its still lofty production cost, principally the number of data to be collected.

In many cases, the data collection process is rendered impossible for diverse motives, such as disinterest on the part of companies or productive sectors, confidentiality on the use of certain inputs and technologies, or the reticence of many corporations in drawing the attention of environmental agencies and non-governmental organizations to their productive systems.

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