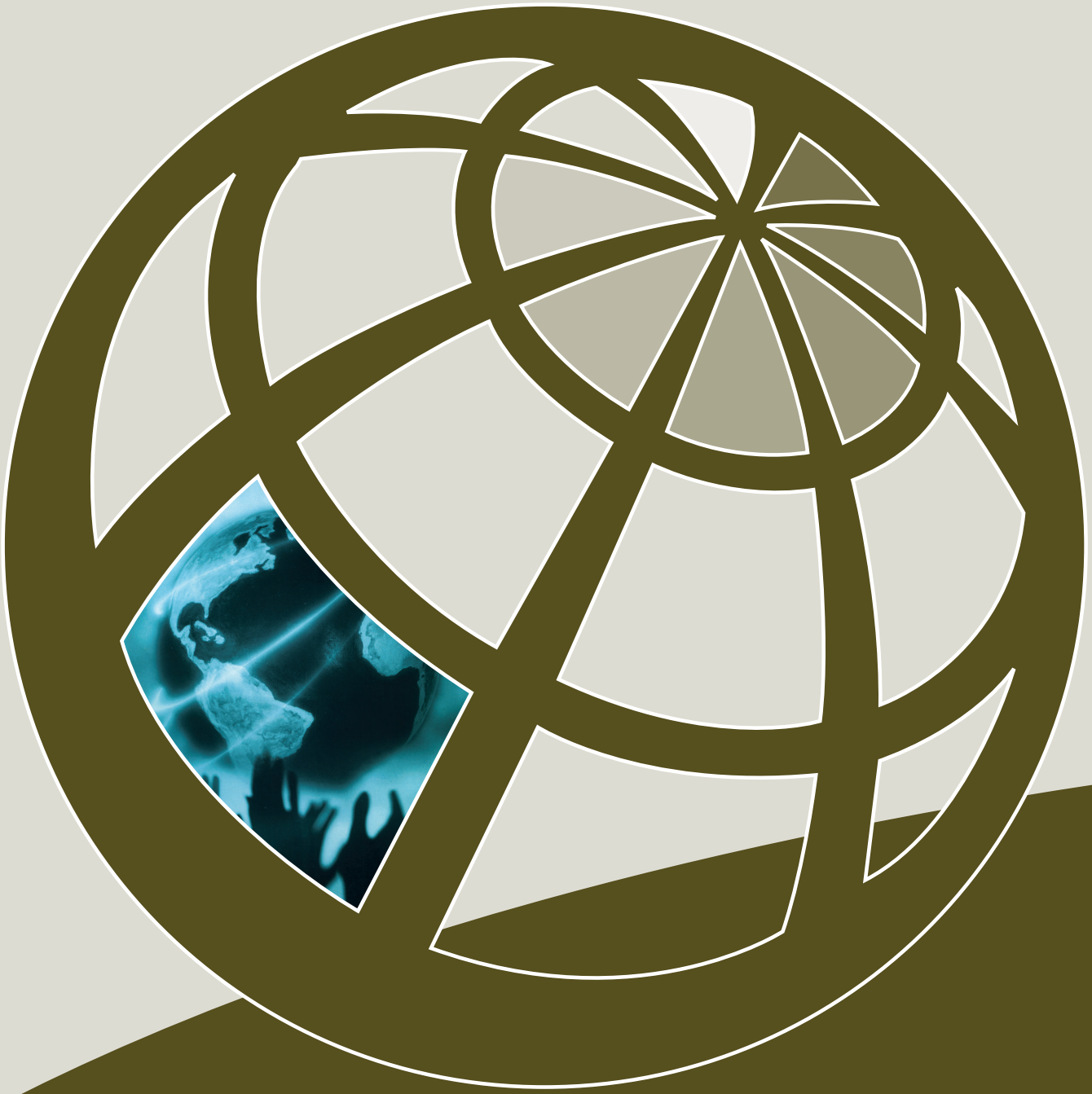

Integrated Environmental Management Information Series

Life Cycle Assessment

9

Department of
Environmental Affairs and Tourism

Other topics in the series of overview information documents on the concepts of, and approaches to, integrated environmental management are listed below. Further titles in this series are being prepared and will be made available periodically. Sequence of release and titles are subject to change.

Information Series 0:	Overview of Integrated Environmental Management
Information Series 1:	Screening
Information Series 2:	Scoping
Information Series 3:	Stakeholder Engagement
Information Series 4:	Specialist Studies
Information Series 5:	Impact Significance
Information Series 6:	Ecological Risk Assessment
Information Series 7:	Cumulative Effects Assessment
Information Series 8:	Cost Benefit Analysis
Information Series 9:	Life Cycle Assessment
Information Series 10:	Strategic Environmental Assessment
Information Series 11:	Criteria for determining Alternatives in EIA
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Information Series 13:	Review in Environmental Impact Assessment
Information Series 14:	Environmental Auditing
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PREFACE

This document is one of a series of overview information documents on the concepts of, and approaches to, integrated environmental management (IEM). IEM is a key instrument of South Africa's National Environmental Management Act (NEMA). South Africa's NEMA promotes the integrated environmental management of activities that may have a significant effect (positive and negative) on the environment. IEM provides the overarching framework for the integration of environmental assessment and management principles into environmental decision-making. It includes the use of several environmental assessment and management tools that are appropriate for the various levels of decision-making.

The aim of this document series is to provide general information on techniques, tools and processes for environmental assessment and management. The material in this document draws upon experience and knowledge from South African practitioners and authorities, and published literature on international best practice.

This document is aimed at a broad readership, which includes government authorities (who are responsible for reviewing and commenting on environmental reports and interacting in environmental processes), environmental professionals (who undertake or are involved in environmental assessments as part of their professional practice), academics (who are interested in and active in the environmental assessment field from a research, teaching and training perspective), non-government organisations (NGOs) and interested persons. It is hoped that this document will also be of interest to practitioners, government authorities and academics from around the world.

This document has been designed for use in South Africa and it cannot reflect all the specific requirements, practice and procedures of environmental assessment in other countries.

This series of documents is not meant to encompass every possible concept, consideration, issue or process in the range of environmental assessment and management tools. Proper use of this series of documents is as a generic reference, with the understanding that it will be revised and supplemented by detailed guideline documents.

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Note

All sources used have been acknowledged by means of complete references.

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SUMMARY

Life cycle assessment (LCA) is the calculation and evaluation of the environmentally relevant inputs and outputs and the potential environmental impacts of the life cycle of a product, material or service. The life cycle consists of the technical system of processes and transport routes used at, or needed for, raw materials extraction, production, use and after use (waste management or recycling). LCA is sometimes called a "cradle-to-grave" assessment. The users of LCAs include:

* industry and other commercial enterprises;
* national governments and local, national and intergovernmental regulatory bodies;
* NGOs (consumer organisations and environmental groups); and
* consumers (which includes governments as consumers).

LCA approaches are generally guided by standards but a professional code of practice has also been developed. LCA generally has four components:

(i) goal and scope;
(ii) inventory;
(iii) impact assessment; and
(iv) improvement assessment.

There are three different types of LCA. They are: i) Conceptual LCA – Life Cycle Thinking, ii) Simplified LCA; and iii) Detailed LCA. The different types can be used in different ways and have strengths and weaknesses, depending upon the context in which they are used. LCAs are currently used by many companies, to provide them with the information they need to respond to market demands, legislative pressures and to explore improved product development and design. Sustainable development, the "Triple Bottom Line", and an increased focus upon high standards in corporate governance and transparency are placing new demands on companies to include the social and ethical dimensions into LCA. It would seem that the further maturing of LCA will require a wider involvement of stakeholders to try and "fill the gaps" in the social and ethical dimensions.

The challenges for LCA are:

* absence of a perceived need for LCA;
* scarcity of LCA expertise;
* access to high quality data; and
* incorrect perception of the applications of LCA in relation to other tools.

CONTENTS

1. INTRODUCTION

The third Chapter of the World Summit on Sustainable Development (WSSD) Johannesburg Plan of Implementation (United Nations, 2002) included a call for, "...the development of a 10 year framework of programmes in support of regional and national initiatives to accelerate the shift towards sustainable consumption and production patterns that will promote social and economic development within the carrying capacity of ecosystems..." The use of life cycle approaches and thinking can contribute information towards the development of practical action plans and programmes to address unsustainable consumption and production patterns.

The purpose of this document is to provide a basic introduction to Life Cycle Assessment (LCA). The text has been purposefully written for a wide audience and sets out to explain and discuss some of the key activities in LCA.

The document gives insights into LCA by providing lessons learned and information from practice. It is expected that this publication will be of use to academics, advocacy groups, civil society groups, environmental practitioners, government authorities, Interested and Affected Parties (I&APs), industry, project proponents, and students.

2. WHAT IS LIFE CYCLE ASSESSMENT (LCA)?

Life cycle assessment (LCA) is the calculation and evaluation of the environmentally relevant inputs and outputs and the potential environmental impacts of the life cycle of a product, material or service (SABS ISO, 1998). Environmental inputs and outputs refer to demand for natural resources and to emissions and solid waste. The life cycle consists of the technical system of processes and transport routes used at, or needed for, raw materials extraction, production, use and after use (waste management or recycling). LCA is sometimes called a "cradle-to-grave" assessment. LCA approaches are generally guided by standards but a professional code of practice has also been developed (Consoli et al. 1993).

LCA generally has four components. These include:

(v) goal and scope;
(vi) inventory;
(vii) impact assessment; and
(viii) improvement assessment.

(i) Goal and scope
The goal and scope definition phase is the first step in a LCA study. In this phase the purpose of the study is described. This description includes the intended application and audience, and the reasons for carrying out the study. Furthermore, the scope of the study is described. This includes a description of the limitations of the study, the functions of the systems investigated, the functional unit, the systems investigated, the system boundaries, the allocation approaches, the data requirements, data quality requirements, the key assumptions, the impact assessment method, the interpretation method, and the type of reporting.

(ii) Inventory
In the Life Cycle Inventory (LCI) analysis, data are collected and interpreted, calculations are made and the inventory results are calculated and presented. The analysis results in a flow model of the technical system. Emissions, energy requirements and material flows are calculated for each process. These data will then be adapted and/or weighted to the functional unit, which is defined in the goal and scope, so that the whole life cycle of the product can be taken into account

(iii) Impact Assessment
In the Life Cycle Impact Assessment (LCIA), the product or production system is examined from an environmental perspective using category indicators. The LCIA also provides information for the interpretation phase.

For comparative assertions, there are four mandatory elements of LCIA:
* selection of impact categories, category indicators and models,
* assignment of the LCIA results (classification),
* calculation of category indicator results (characterisation), and
* data quality analysis.

The following elements are optional:
* calculating the magnitude of category indicator results relative to a reference value (normalisation),
* grouping, and
* weighting

(iv) Improvement assessment
The Improvement Assessment is the phase where the results are analysed in relation to the goal and scope definition, where conclusions are reached, the limitations of the results are presented and where recommendations are provided based on the findings of the preceding phases of the LCA (Following ISO 14043).

A LCA is generally an iterative process (i.e. its stages are repeated as more information is gathered or systems better understood). The impact assessment helps to increase the knowledge and understanding about which of the environmental inputs and outputs are significant. This knowledge can be used in the collection of better data for those inputs and outputs in order to improve the inventory analysis. The conclusions of the LCA should be compatible to the goals and quality of the study.

In summary, the "goal and scope" will define the limits of the study, the "inventory" will consist of a full listing and categorisation of the different elements involved in the cycle, the "impact assessment" describes and quantifies the impacts and the "improvement assessment" is the basis for improvement of the existing cycle.

The LCA can be viewed from two main perspectives:
* as a conceptual thought process that guides the selection of options from design and improvement; and
* methodologically, as a way to build a quantitative and qualitative inventory of environmental burdens or releases, to evaluate the impacts of those burdens or releases, and to identify alternatives to improve environmental performance (Fava, 1997).

LCA methods and techniques assist in decision making by looking at the production, use and disposal of a product or service. It provides information on the environmental burden at all stages, and thus enables a choice to be made on both an economic and a resource usage, or environment-based perspective.

3. TYPES OF LCA

There are three different types of LCA. They are: i) Conceptual LCA – Life Cycle Thinking, ii) Simplified LCA; and iii) Detailed LCA. The different types can be used in different ways and have strengths and weaknesses, depending upon the context in which they are used. Table 1 below illustrates how the differing LCA types can be used and which types are used for preferred options.

3.1 Conceptual LCA

The conceptual LCA is the simplest form of LCA and is used at a very basic level to make an assessment of environmental aspects, based upon a limited and usually qualitative inventory. The results of a conceptual LCA can usually be presented using qualitative statements, graphics, flow diagrams or simple scoring systems which indicate which components or materials have the largest environmental impacts and why.

The results of Conceptual LCAs are not suitable for marketing purposes or for public dissemination. They may, however, help decision makers identify which products have a competitive advantage in terms of reduced environmental impacts. The term, "Life Cycle Thinking" is sometimes used instead of "Conceptual LCA" (UNEP-DTIE, 2003).

3.2 Simplified LCA

Simplified LCA applies the LCA method for a screening assessment (i.e. covering the whole life cycle). But it does so superficially by using generic data and standard modules for energy production. This is followed by a simplified assessment that focuses on the most important environmental aspects and/or stages of the life cycle and a thorough assessment of the reliability of the results.

Simplification of LCA consists of three stages:

* Screening: Identifying those parts of the system (life cycle) or of the elementary flows that are either important or have data gaps;
* Simplifying: Using the findings of the screening in order to focus further work on the important parts of the system or the elementary flows; and
* Assessing reliability: Checking that simplifying does not significantly reduce the reliability of the overall result.

3.3 Detailed LCA

Detailed LCAs involve the full process of undertaking LCAs and require extensive and in-depth, data collection, specifically focussed upon the target of the LCA, which if only available generically, must be collected specifically on the product or service under review.

Table 1: Level of detail in the application of Life Cycle Assessment (Jensen, 1997).
(Number 1 indicates the most frequently used type of LCA in certain contexts or environments)

Level of detail in LCA				
Application	Conceptual	Simplified	Detailed	Comments
Design for Environment	1	x		No formal links to LCA
Product development	x	1	x	Large variation in sophistication
Product improvement		x		Often based on already existing products
Environmental claims (ISO type II –labelling-ISO 14021)	1			Seldom based on LCA
Ecolabelling (ISO type I – labelling-ISO 14024)	x			Only criteria development requires a LCA
Environmental declaration (ISO type III-labelling- ISO 14025)			x	Inventory and/or impact assessment
Organisation marketing		1	x	Inclusion of LCA in environmental reporting
Strategic planning	1	1		Gradual development of LCA knowledge
Green procurement	x	1		LCA not as detailed as ecolabelling
Deposit/refund scheme		x		Reduced number of parameters in the LCA is often sufficient
Environmental ("green") taxes		x		Reduced number of parameters in the LCA is often sufficient
Choice between packaging systems	x		1	Detailed inventory. Scope disputed LCA results not the only information

4. HISTORY OF LCA

The energy crises in the 1970s and the resource depletion concerns raised by publications such as "Limits to Growth" (Meadows, et al., 1972) set a trend where more thought began to be given to ways and means of optimising resource usage. Rising energy costs triggered the need for more systematic and detailed energy usage planning. (UNEP-IE, 1996) LCA developed in parallel to energy planning initiatives and the need for detailed energy analyses spawned further thinking on waste and emissions analyses within LCA.

A growing focus upon global warming and resource depletion influenced an increased interest in LCA during the 1980's. This was accompanied by more LCA studies being made available publicly. It was at this stage that databases began to be developed to meet the complex inventory and assessment data needs of the studies.

By the time of the 1992 UN Earth Summit, there was a ground swell of opinion that life cycle assessment methods were amongst the most promising new tools for a wide range of environmental management tasks. A series of issues in 1995 and 1996, particularly the planned disposal of the Brent Spar oil buoy[1] , and the significant economic and social dislocations caused by public reactions to "mad cow disease" (BSE), helped to re-ignite interest in life cycle assessment thinking. (Jensen et al., 1997) The Brent Spar issue illustrated that LCA methods needed to be used for major installations and structures, in addition to consumer goods such as detergents, baby nappies and washing machines, to generate the information and analytical techniques to enable quantitative and qualitative comparisons to be made. In simple terms, "what are the best options, environmentally, and what data and analysis supports these options?"

LCAs are currently used by many companies, in-house, to provide them with the information they need to respond to market demands, legislative pressures and to explore improved product development and design. Much of this information is kept confidential as a part of the strategic and competitive initiatives of various companies. Sustainable development, the "Triple Bottom Line", and an increased focus upon high standards in corporate governance and transparency are placing new demands on companies to include the social and ethical dimensions into LCA. It would seem that the further maturing of LCA will require a wider involvement of stakeholders to try and "fill the gaps" in the social and ethical dimensions.

5. WHO USES LCA AND WHY?

There are essentially four types of users of LCAs (Jensen, 1997):

* industry and other commercial enterprises;
* government and regulatory bodies;
* NGOs (consumer organisations and environmental groups); and
* consumers (which includes governments as consumers).

[1] *Shell, the owners of the North Sea Brent Spar oil buoy, proposed to sink the obsolete buoy in deep water and there was an outcry that this was an inappropriate option and other alternatives should be considered. The various options (towing to shore and dismantling, decontamination and sinking to create a reef, refurbishment and sale, etc.) were incorporated in a LCA to evaluate and assess the options.*

5.1 Industry and other commercial enterprises

Companies tend to be legally responsible for only a small part of the life cycle of their products. However, there is a growing trend in both legislation and society towards holding manufacturers accountable for the actions and consequences of their products and services (this is known as "chain responsibility"). Whilst this aspect may be difficult to legislate, the damage that can be done to a company's reputation or product credibility can be enormous.

LCA is a tool, which can help to understand the various environmental benefits and liabilities (identified and unidentified) that exist in the product or service that they produce. Understanding these also helps in public discussions on the environmental effects of their operations. The results from the LCA can help in the communication of information when engaging with stakeholders (i.e. environmental organisations, communities, interested and affected parties and government authorities).

The main applications of LCA in industry are in product improvement, product design, formulation of company policy, product information, and use in negotiations.

Product Improvement

LCAs are prepared by manufacturers to create a base from which to improve and develop the product or the means of production of the product. The information is normally developed for internal use, is kept confidential and forms a key part of the means of maintaining a competitive edge in the marketplace. The cost of undertaking this work is high and its value to existing and new participants in the market place is very significant.

Product Design

New products are often developed from old designs and concepts and the LCA is a useful means of taking "old information" and comparing it with projections and estimates for new product and services. Whilst the line between improvement and new design is narrow, the differential for motivating, for example, for capital expenditure on upgrading or replacing plant and machinery can benefit significantly from product design LCAs.

Formulation of Company Policy

LCAs can contribute significantly to the development and modification of company policies in specific areas. For example, guidance on the choice of raw materials could directly affect a company's strategy for handling waste materials. In some cases, it could result in a reduction in generation of hazardous waste, increased recycling potential, or a reduction in quantities of industrial waste that needs to be landfilled. LCAs could also guide companies in avoiding specific raw materials and chemicals which could be seen as problematic in terms of materials handling or public perceptions.

Product Information

Government authorities might in some instances, require product information for the purposes of licensing or legal compliance. Information produced from LCAs can supply this requirement and the "documentary audit trail" created by the LCA is a mechanism that can assist in confirming the validity of data and product-related decisions and choices.

Use in Negotiations

Authorities in South Africa are applying significant pressure on manufacturers to use cleaner production methods and techniques. Information sourced from LCA can help to maintain a balance to ensure that authority requirements are based upon verified data and practicality. The results can also be used to support discussions relating to the "best practice", "best practicable option" and "best practicable environmental option" when negotiating, for example, permits, licences and approvals.

5.2 Government and regulatory bodies

LCAs play a major part in promoting the basic principles of sustainable development and therefore government structures can utilise the information contained in the studies. Furthermore, by promoting the wider use of LCAs, government is encouraging better information gathering on sustainability issues in the context of the economy and economic activity.

The specific areas where LCAs can be used by government are eco-labelling, deposit-refund schemes, subsidies and taxation and in general policies.

Eco-labelling (Environmental labelling)

Whilst eco-labelling has not yet become an established part of regulatory structures in South Africa, the direction set by the European Union and North America suggests that the benefits in some areas could well encourage the government to consider some form of eco-labelling scheme in the not to distant future.

Eco-labelling is a mechanism of granting recognition for products that achieve a certain minimum standard in "environmental friendliness".

Some observers believe that eco-labelling standards could become the next manifestation of environmental trade barriers, in the same way that environmental issues are used as trade barriers against goods from developing countries entering Europe and North America.

Deposit-Refund Systems

Decision making on whether or not to introduce deposit-refund systems to encourage recycling and reuse of raw materials is a difficult task. The goal is to make the cost of waste disposal higher and to encourage the closing of material cycles to optimise production systems. Detailed LCAs can provide both the information on the energy and material flows and the qualitative data to enable assessment to be made on the viability of deposit-refund systems.

Subsidies and Taxation

Decisions on introduction or shifts in taxation or subsidies require detailed quantitative studies to predict how they will affect markets and production. Qualitative detailed LCAs can provide information to inform decisions and can also illustrate how, for example, the purchase and production of cleaner products can be stimulated through subsidies such as low interest loans for manufacturing investments.

General Policies

General policy can be informed by detailed LCAs, particularly on issues such as whether dangerous goods should be transported by road or rail or how the promotion of differing energy sources (i.e. electricity, coal, oil or paraffin) can be promoted, depending upon availability, strategic planning or market flexibilities.

5.3 NGOs

LCAs can provide NGOs with valuable base information on which to inform their members and also to motivate for change and improvement. At the present time, LCAs do not have a very high profile with NGOs in South Africa and in some cases, LCAs are seen as biased documents. This may be influenced by the fact that, particularly in South Africa at the present time, there is a shortage of skilled LCA practitioners and government has not given clear and pubic statements on how it sees LCAs in the future. Furthermore, government has not clearly indicated how it intends to use LCA within its own activities and processes.

There is a potential in the future for the information in LCAs to be subject to the provisions of South Africa's Promotion of Access to Information Act. If NGOs can negotiate with industry to ensure that core LCA data is freely available in the context of transparency and open corporate governance provisions, then communication of information on products is less likely to create problems.

5.4 Consumers

LCA information should help to inform the consumer on the purchasing options that have to be made. At the present time, LCA is unknown to the consumer and therefore of little help in, for example, purchasing decisions on whether or not environmentally friendly goods should be purchased and the value thereof. This relates to the limited use of LCAs in South Africa and the shortage of skilled practitioners that can apply the LCA methods.

In the future, statutory and NGO consumer organisations will obtain valuable information from LCAs carried out on various consumer goods and services. By communicating the results of these studies to the public, they will be able to influence consumer buying patterns and assist the consumer in making wise purchase choices. For example, washing machines can be high users of water and energy and, if poorly designed, could contribute significantly to increased phosphate loading in the environment. By providing consumers with the information to make good decisions not only on price but also running, costs and pollution potential, national environmental protection policies and goals become easier to implement and data can be used to illustrate how changes and improvements can reduce pollution in the short and long term.

6. LEGAL AND POLICY STATUS OF LCA IN SOUTH AFRICA

There is no requirement in law in South Africa to carry out LCA studies and there is limited reference to LCA in government policies and documentation. LCA is, however, an environmental management tool that is needed to enable scientifically based decision making to implement some of the National Environmental Management Act Principles.

South African legislation holds waste generators responsible for their waste materials with no time limit and on a co-responsibility basis with their waste disposal contractors. In this case, it becomes crucial that the generators fully understand the nature and consequences of all the waste products (and some by-products) emanating from the production process, as a means of both limiting legal responsibility and identifying those areas where minimisation or substitution may be necessary because of the unacceptable legal, financial and environmental risks associated with the use of materials. Although LCA is not a legal requirement in South Africa, LCA studies have been undertaken in academic institutions and within some sectors of industry. LCA researchers have carried out LCA studies at the Universities of Natal, Cape Town, and Pretoria (which has a Chair of Life Cycle Engineering), the Pretoria Technikon and the CSIR (EPS Group). Companies such as Sasol, Mondi, Impala Platinum and Eskom have undertaken LCA studies (Chris Buckley, pers comm).

An African LCA Network linked to the UNEP/SETAC LCA Initiative has recently been launched and there is a clear recognition that the gap between LCA in Developed and developing Nations needs to be bridged.

7. LCA STANDARDS

From a standards perspective, LCA is dealt with under the umbrella of the ISO 14000 series. The main documents are as follows:

* ISO 14040 – Life Cycle Assessment – Principles and Framework (1997)
* ISO 14041 – Life Cycle Inventory Analysis (1998)
* ISO 14042 – Life Cycle Impact Assessment (2000)
* ISO 14043 – Life Cycle Interpretation (2000)

Table 2 below provides a summary on the contents of the LCA and environmental labelling standards. It should be noted that not all of the standards have yet been published by Standards South Africa (previously the South African Bureau of Standards) and some are only obtainable directly from the International Standards Organisation (ISO) in Geneva or can be ordered via Standards South Africa.

Table 2: ISO 14000 standards related to product systems (adapted from UNEP-DTIE, 2003)

Using Environmental Declarations and Claims	Conducting Life Cycle Assessment (LCA)	Understanding the Standards
ISO 14020 General principles or the basis of the development of ISO guidelines and standards on environmental claims and declarations	ISO 14040 General principles, framework and requirements for the LCA of products and services	ISO 14050 Understanding the terms used in the ISO 14000 series standards
ISO 14021 Guidance on the terminology, symbols, and testing and verification methods that should be used for self-declaration of the environmental aspects of products and services	ISO 14041 Guidance on determining the goal and scope of a LCA study and for conducting a life cycle inventory	
	ISO 14042 Guidance on conducting the LCIA phase of LCA	
ISO 14024 Guiding principles and procedures for third party environmental labelling certification programmes.	ISO 14043 Guidance on the interpretation of results from a LCA study	
ISO 14025 Guidance and procedures on a specialised form of third party environmental labelling certification using quantified product information labels	ISO 14047 Provides illustrative examples on how to carry out a LCIA	
	ISO 14048 Information on formatting of data to support LCA	
	ISO 14049 Examples that illustrate how to apply the guidance in ISO 14041	ISO Guide 64:1997 Document helps the writers of product standards to address aspects in those standards

8. PROCESS INVOLVED IN UNDERTAKING A LCA

ISO 14040 provides a model for the approach to undertake a LCA. (See Figure 1). Figure 2 illustrates the procedure for LCA, which is described below.

i. Goal and Scope Definition
The product or service to be assessed is defined. A functional basis for comparison is chosen and the required level of detail is defined.

ii. Inventory Analysis
The energy carriers, raw materials, emissions to atmosphere, water and soil and different types of land use are quantified for each process. These are all combined in the process flow chart and related to the functional basis.

iii. Impact Assessment
The effects of the resource use and emissions generated are grouped and quantified into a limited number of impact categories which may then be weighted for comparison.

Figure 1: Life Cycle Assessment framework based on the ISO 14040 model

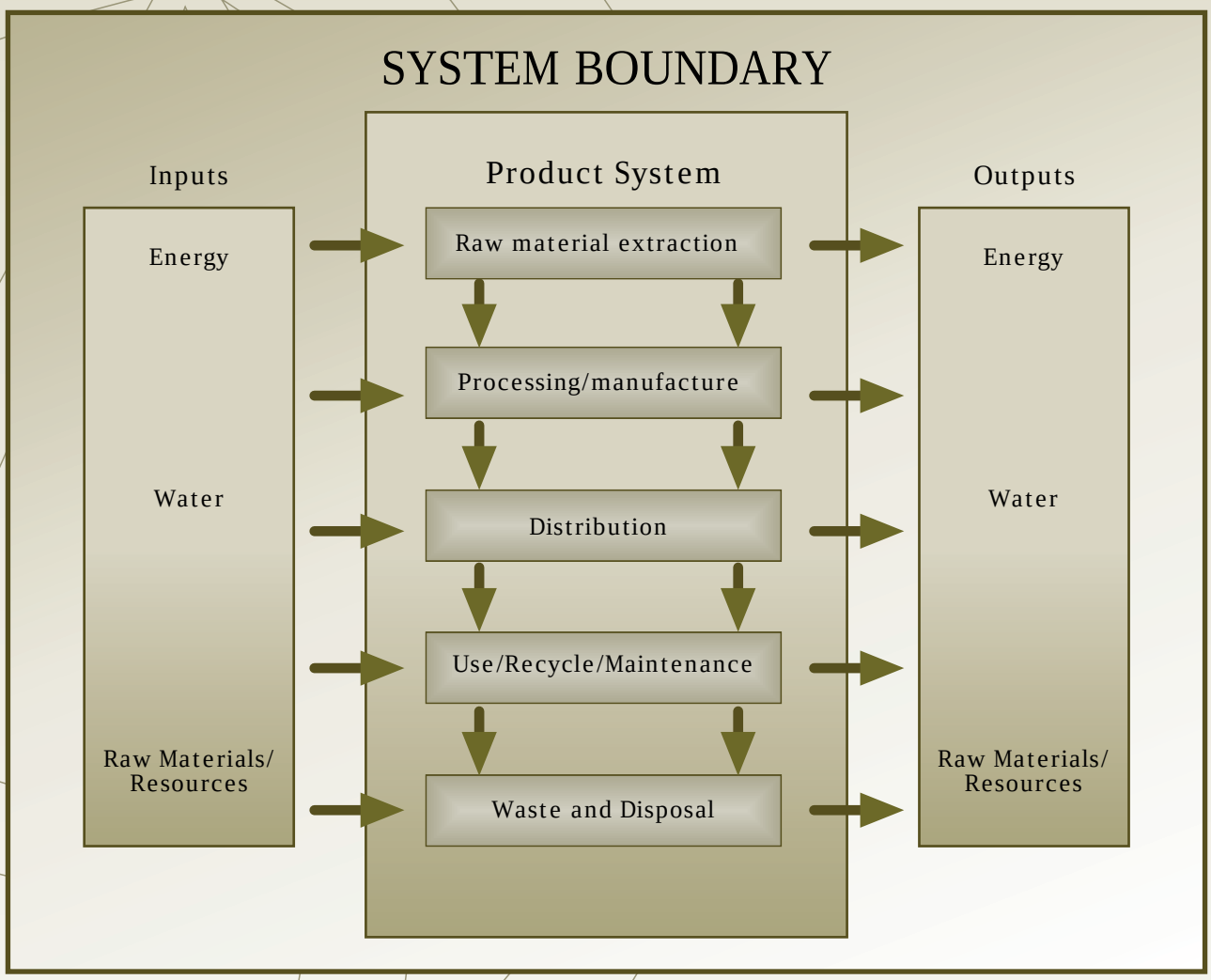
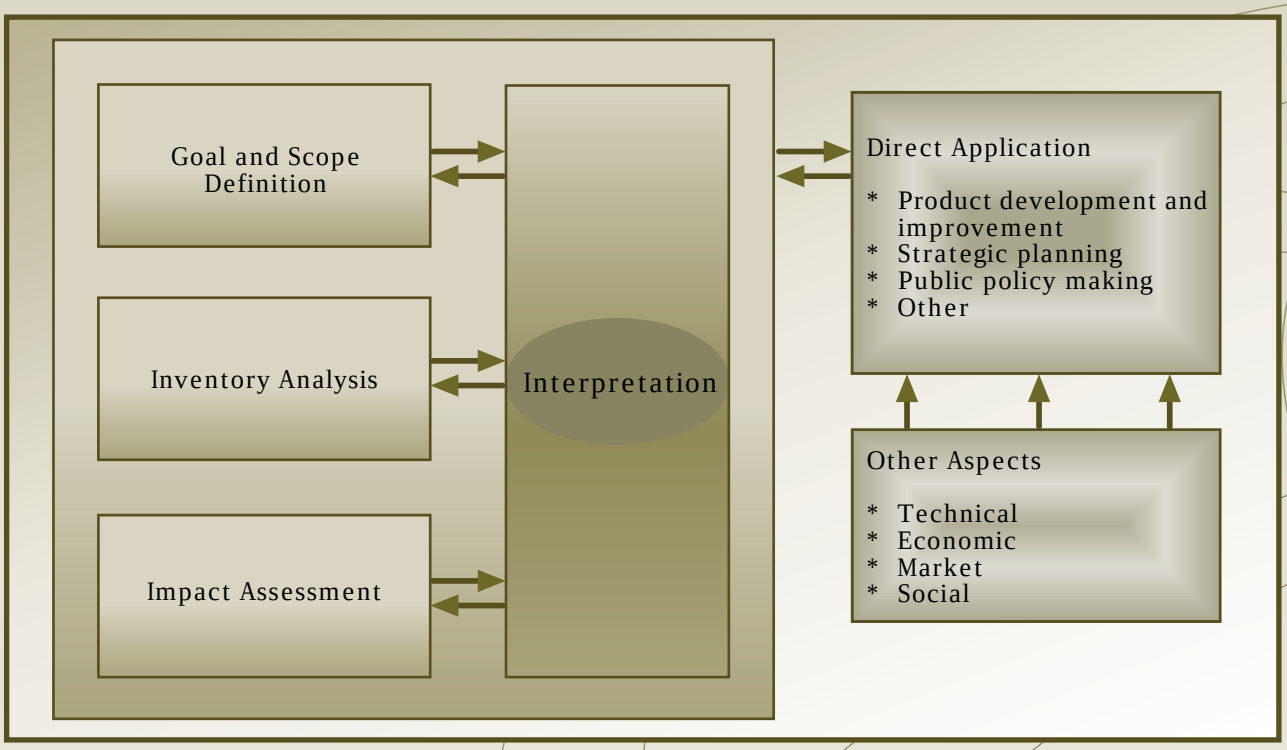


Figure 2 illustrates how the various activities within a typical factory or plant are grouped and this provides the basis for undertaking the LCA. The conceptual LCA will map the processes into a flow chart which broadly migrates from inputs (raw materials) through processing (product or production system) through to outputs (finished goods, by-products and wastes). Simplified and detailed LCAs will, in various levels of detail and complexity, quantify, classify and categorise, the impacts at different stages.

Figure 2: Illustration of Life Cycle Assessment Procedure



The Detailed LCA method can be split into five stages (Consoli, et al, 1993). These are:

i. Planning
* statement of objectives;
* definition of the product and its alternatives;
* choice of system boundaries;
* choice of environmental parameters;
* choice of aggregation and evaluation method; and
* strategy for data collection.

ii. Screening
* preliminary execution of the LCA; and
* adjustment of plan.

iii. Data collection and data treatment
* measurements, interviews, literature search, theoretical calculations, database search, qualified guessing; and
* computation of the inventory table.

iv. Evaluation
* classification of the inventory table into impact categories;
* aggregation within the category (characterization);
* normalization; and
* weighting of different categories (valuation).

v. Improvement assessment
* sensitivity analysis; and
* improvement priority and feasibility assessment.

It is generally recognized that the first stage (i.e. planning) is extremely important. The result of the LCA is heavily dependent on the decisions taken in this phase. The screening LCA is a useful step to check the goal-definition phase. After screening it is much easier to plan the rest of the project.

8.1 Strengths and Weaknesses of LCAs

Strengths
After more than two decades of LCA work in Europe and North America, there is a growing body of information in the form of databases on raw materials, intermediaries, energy technologies and transportation modes. This experience will help to fast track some of the LCA initiatives that could develop in South Africa. Although some of that data relates to developed world experiences, other collected data can be used, in conjunction with local developed data and impact categories and/or extrapolated to apply to South African conditions.

The applications that can benefit from the results of LCAs are significant. LCA initiators can get a better understanding of exactly what their operations impact upon. The information is quantified in a manner which permits comparison and analysis. Life Cycle thinking is a cornerstone for developing policies and programmes which meet sustainability criteria. The systems and standards will ultimately result in even comparison criteria enabling effective scientific benchmarking to be carried out. Government will be able to evaluate performance using LCA and set legislative standards and requirements based upon accurate, detailed and practical systems data.

Specific strengths of LCA include:
* the “cradle to grave” approach of LCA extends beyond the usual boundaries of Environmental Impact Assessments;
* the use of diagrams to illustrate the flows, stages and processes of LCA is a valuable cognitive tool for capacity building;
* the LCA is able to effectively identify and track environmental pollution moving between air, water and soil; and
* the use of scores, with reliable data sets and impact categories, enables effective comparisons to be made between products and processes in a manner that is broader than can be achieved in Environmental Impact Assessments.

Weaknesses

There are weaknesses and limitations in the use of LCAs which need to be understood. Some of these include:

* studies relate primarily to normal operating conditions. Abnormal events such as spills and incidents can only be effectively accommodated through the parallel use of risk assessments;
* limited data, questionable data quality and varying regional relevancy, is a constricting factor, especially in South Africa (this is particularly problematic when local studies are used in juxtaposition to similar developed world, detailed LCA studies);
* there are data shortages and limitations (including region specific differences) for a number of the impact categories, especially areas such as eco-toxicity and human toxicity, soil erosions and biodiversity change (The lack of confidence in data in these areas means that the environmental scores could be unreliable.);
* reliability upon the environmental scores for decision making is heavily dependent upon confidence in the data sets and the skill and expertise of the local LCA practitioners in judging this, in the context of other European- or North America-based LCA studies;
* assumption of potential worst case scenario environmental effects in an "all or nothing" perspective (For example, in the case of the acidification category in impact assessment, all acid emissions are considered, even though emissions may be neutralised in alkaline mediums);
* lCA assumes linearity of impact, i.e. the greater the pollutant, the greater the impact, which does now allow for variability in local conditions or critical loads;
* project and investment actions can be delayed because it takes long to conduct a detailed LCA;

LCAs are regularly repeated and as information is acquired and technologies change, the results carried out in one year may contradict the results of an older LCA.

A data supported, analysis based decision tool, such as a LCA, can have inherent design faults if there are no standards in place to cover study approaches and study design parameters. The results of LCAs can be flawed if the wrong questions are asked, the wrong data is used or the analysis is wrong or inappropriate. These problems can only be overcome if there are clear and transparent guidelines and robust peer review mechanisms to help ensure that the highest of standards are maintained in study approach and technique.

8.2 International Perspectives on LCA

LCA as a business tool is well established and is widely used by goods and services industries. Car manufacturers such as BMW and Volvo use LCA techniques to compare methods and materials to make their vehicles more recyclable and to reduce the generation of hazardous waste in both the manufacturing and disposal phase. Chemical companies such as Dow, 3M, BASF, Unilever and Bristol-Myers Squibb use LCA as a means of testing their products (actual and anticipated) for legal compliance and for eco-friendliness. Samsung Electronics used LCA to study the environmental performance of a colour computer monitor. The tool is thus well established as a mechanism and proven as a credible contributor to the business decision-making process. Much has been achieved since Coca-Cola first used LCA, commercially, in a packaging study in 1969.

It would appear, however, that a plateau has been reached in the further development of LCA, internationally. Recent international workshops (UNEP-DTIE, 2003) have made significant progress in consolidating efforts and achievements to date but have identified a number of challenges which face further development. The challenges are:

* Absence of a perceived need for LCA
  A general lack of environmental awareness and a lack of drivers for chain management and responsibility have created a barrier to development. One of the major impediments for life cycle based policies is the "Stockholm Principles" which state that every country is responsible for its own resources, as long as it causes no harm to any other country. A further complication is the World Trade Organisation agreement that forbids discrimination on the basis of environmental information.

* Scarcity of LCA expertise
  It was noted that there is a scarcity of expertise for performing and understanding LCA studies in developing countries. This was further amplified in the comments that communication about LCA methods and study outputs, particularly to policy makers is a problem.

* Cost of LCA Studies
  The high level of expert knowledge required by complex LCAs, coupled with the need to purchase data from commercial databases suggest high costs, this is compounded by the added costs of ISO requirements for review.

* Access to High Quality Data
  Data quality and availability, particularly for developing countries creates a major practical bottleneck in LCA studies.

* Lack of user-friendly and widely recognised LCIA methods
  Methodological barriers in LCIA are related to the lack of generally agreed methods and this appears not to be adequately addressed through ISO standardisation.

* Incorrect perception of the applications of LCA in relation to other tools
  There is an incorrect perception of the applicability of LCA and its relationship to other environmental management tools. For example, sophisticated LCIA studies are frequently, incorrectly, compared to environmental risk assessment studies.

As a result of these issues, a "Life Cycle Initiative" on approaches and best practice for a life cycle economy was launched (UNEP-DTIE SETAC, 2002). The initiative is focussing upon the area of Life Cycle Impact Assessment and best practice.

9. CONCLUSIONS

The Conceptual LCA will contribute substantially to the quality of integrated decision making, particularly against the context of a government's commitments to sustainable development. As an additional tool in the environmental management toolbox, it will assist in raising awareness on integrated environmental management and sustainability issues and will encourage a greater degree of inter-disciplinary linkages. There is room for greater use of Simplified and Detailed LCAs in South Africa. Current usage is limited but significant growth in this area will depend upon extensive capacity building in both academic and technical fields. Co-operative projects such as the LCA Initiative will assist in not only developing the skills and expertise but also by bridging the gap in terms of databases, development of localised categories and harmonisation of methodologies that cut across the current "North-South" Divide.

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http://www.eiolca.net

International Organisation for Standardisation – Guide to ISO On-Line
http://www.iso.ch/iso/en/xsite/guide.html#Abbrev

Introduction to LCA for Purchasing Agents (On-line slide show given in Seattle, 10th May 2001 by Rita C Schenk)
http://www.iere.org/slides/Seattle-Purchasing/index.htm

LCA Beginner's Corner
http://www.lcacenter.org/LCA/begin.html

LCA Hotlist
http://www.doka.ch/lca.htm

Life Cycle Assessment Links
http://www.life-cycle.org

Life Cycle Analysis System for Cities
http://www.gdrc.org/uem/lca/lca-for-cities.html

Memorial site for the Society for Promotion of Life-cycle Assessment Development (SPOLD)
http://lca-net.com/spold/

Results of LCA Case Studies
http://www.doka.ch/lca.htm#Results

SETAC Life Cycle Assessment Advisory Group
http://www.setac.org/lca.html

Standards South Africa – Source to purchase South African National standards.
http://www.stansa.co.za/

UNEP-TIE – Environmental Management Tools – LCA. Simple explanations of range of environmental management tools plus manuals and guidelines on their use.
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Unilever – Life Cycle Assessment
http://www.unilever.com/environmentsociety/environmentalmanagement/lifecycleassessment/

US Environmental Protection Agency – Life Cycle Assessment
http://www.epa.gov/ORD/NRMRL/lcaccess/

Selected LCA Software on the Internet
(All the software access links have all been checked at the time of writing. Should the links be broken, go to the main site home page and search for the software on the site.)

Eco-Indicator by PRé Consultants BV is abridged LCA software, aimed at designers, which contain limited data but allows simple Life Cycle Impact evaluation studies and helps designers the understand the basics of LCA thinking. Go to http://www.pre.nl

CMLCA by Centre of Environmental Science (CML) - Leiden University. Chain Management by Life Cycle Assessment (CMLCA) is a software tool that is intended to support the technical steps of the LCA procedure. The (free) program can be downloaded from
http://www.leidenuniv.nl/interfac/cml/ssp/software/cmlca/index.html

LCAit is a simple graphics based software that allows the user to set up a product life cycle graphically and allows material and input/output balances. A Lite version of the software maybe be downloaded free for evaluation purposes at
http://www.lcait.com/01_2.html

KCL ECO operates on a process of modules and flows, each flow consists of a number of equations that represent masses and energies moving between two modules. Software is clear and easy to use. Download a free demo at http://www.kcl.fi/eco/indexn.html

SimaPro 5.1 by PRé Consultants. SimaPro is a professional LCA software tool that contains several impact assessment methods and several inventory databases, which can be edited and expanded without limitation. It can compare and analyze complex products with complex life cycles. A demo version can be downloaded from
http://www.pre.nl/simapro/default.htm

TEAM by the Ecobilan Group and Pricewaterhouse Coopers is a powerful and flexible software package with an extensive database which supports transparency and sensitivity analyses of studies. Go to
http://ecobalance.com

TRACI - Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts, developed by the US Environmental protection Agency. The complete (free) software and user's guide can be downloaded from the website
http://www.epa.gov/ORD/NRMRL/std/sab/iam_traci.htm

11. GLOSSARY

Definitions

Affected environment
Those parts of the socio-economic and biophysical environment impacted on by the development.

Affected public
Groups, organizations, and/or individuals who believe that an action might affect them.

Allocation
This is a step in LCA in which it is decided how environmental interventions of a multiple process will be distributed throughout the various process functions

Alternative proposal
A possible course of action, in place of another, that would meet the same purpose and need. Alternative proposals can refer to any of the following but are not necessarily limited thereto:

* alternative sites for development
* alternative projects for a particular site
* alternative site layouts
* alternative designs
* alternative processes
* alternative materials

In IEM the so-called "no-go" alternative also requires investigation.

Authorities
The national, provincial or local authorities, which have a decision-making role or interest in the proposal or activity. The term includes the lead authority as well as other authorities.

Baseline
Conditions that currently exist. Also called "existing conditions."

Baseline information
Information derived from data which:

* Records the existing elements and trends in the environment; and
* Records the characteristics of a given project proposal

Chain Responsibility
The term that describes the concept that the manufacturer of a product is held responsible not only for its manufacturing operations but also for the uses to which the product is put and the way in which it is disposed of. This chain management and responsibility can be formalised, for example, in Germany, there is a legal requirement for "take back" of certain products such as refrigerators and washing machines at the end of their working lifespans. Similarly, suppliers of these goods are required to take back the packaging of these products, when they are delivered, as a means of encouraging "multi-use packaging" to reduce the generation of excessive packaging.

Characterisation
Characterisation is a step in impact assessment where the environmental interventions (called "Stressors") of a product system are aggregated into a limited number of environmental problems.

Classification
This is the first element within the impact assessment which attributes the environmental interventions listed in the inventory table to a number of selected categories.

Decision-maker
The person(s) entrusted with the responsibility for allocating resources or granting approval to a proposal.

Decision-making
The sequence of steps, actions or procedures that result in decisions, at any stage of a proposal.

Environment
The surroundings within which humans exist and that are made up of -

i. the land, water and atmosphere of the earth;
ii. micro-organisms, plant and animal life;
iii. any part or combination of (i) and (ii) and the interrelationships among and between them; and
iv. the physical, chemical, aesthetic and cultural properties and conditions of the foregoing that influence human health and well-being. This includes the economic, cultural, historical, and political circumstances, conditions and objects that affect the existence and development of an individual, organism or group.

Environmental Assessment (EA)
The generic term for all forms of environmental assessment for projects, plans, programmes or policies. This includes methods/tools such as EIA, strategic environmental assessment, sustainability assessment and risk assessment.

Environmental consultant
Individuals or firms who act in an independent and unbiased manner to provide information for decision-making.

Environmental Impact Assessment (EIA)
A public process, which is used to identify, predict and assess the potential environmental impacts of a proposed project on the environment. The EIA is used to inform decision-making.

Environmental Intervention
This is the name to describe the physical interaction between a system (being studied) and the environment. It is defined in terms of the extraction of resources, emissions to air, water or land, space occupied by waste or structures or area of disturbance.

Fatal flaw
Any problem, issue or conflict (real or perceived) that could result in proposals being rejected or stopped.

Impact
The positive or negative effects on human well-being and/or on the environment.

Impact Categories
These are environmental problems, problem types or environmental themes. The impact categories are scored in terms of the product system's impact contribution. The ISO standard provides a preliminary list of impact categories which can be added to. The list consists of:- abiotic resources, biotic resources, land use, global warming, stratospheric ozone depletion, ecotoxicological impacts, human toxicological impacts, photochemical oxidant formation, acidification, eutrophication, and the work environment. Salinity, as an environmental impact category specific for South Africa, has been developed for incorporation in future local LCA studies (personal communication, Buckley, 2003).

Integrated Environmental Management (IEM)
A philosophy which prescribes a code of practice for ensuring that environmental considerations are fully integrated into all stages of the development and decision-making process. The IEM philosophy (and principles) is interpreted as applying to the planning, assessment, implementation and management of any proposal (project, plan, programme or policy) or activity - at the local, national and international level - that has a potentially significant effect on the environment. Implementation of this philosophy relies on the selection and application of appropriate tools to a particular proposal or activity. These may include environmental assessment tools (such as Strategic Environmental Assessment and Risk Assessment); environmental management tools (such as monitoring, auditing and reporting) and decision-making tools (such as multi-criteria decision-support systems or advisory councils).

Interested and affected parties (I&APs)
Individuals, communities or groups, other than the proponent or the authorities, whose interests may be positively or negatively affected by a proposal or activity and/or who are concerned with a proposal or activity and its consequences. These may include local communities, investors, business associations, trade unions, customers, consumers and environmental interest groups. The principle that environmental consultants and stakeholder engagement practitioners should be independent and unbiased excludes these groups from being considered stakeholders.

Lead authority
The environmental authority at the national, provincial or local level entrusted in terms of legislation, with the responsibility for granting approval to a proposal or allocating resources and for directing or coordinating the assessment of a proposal that affects a number of authorities.

Life Cycle
Consecutive and interlinked stages of a product system, from raw material acquisition or generation of natural resources to final disposal.

Life Cycle Impact Assessment (LCIA)
This is the phase of the LCA which tries to understand and evaluate the magnitude and significance of the potential environmental impacts of a product system.

Life Cycle Inventory (LCI) analysis
This is where an objective analysis is made of the environmental interventions associated with the process or function.

Life Cycle Management (LCM)
LCM has been developed as an integrated concept for managing the total life cycle of products and services towards more sustainable consumption and production patterns. LCM uses procedural and analytical tools and integrates economic, social and environmental aspects into an institutional context.

Mitigate
The implementation of practical measures to reduce adverse impacts.

Non-governmental organizations (NGOs)
Voluntary environmental, social, labour or community organisations, charities or pressure groups.

Normalisation
Normalisation is a sub-step in characterisation where the quantified contributions to the impact categories are related to total magnitude of these impacts as created in a year by all the activities in the world. The resulting figures are called the normalised effect scores. The table below illustrates the numerical scores.

Environmental problem	Quantified contribution	Normalized (years)	Normalized (seconds)
Resource depletion	8,300 kg	3×10^{-7} years	9.46
Global warming	210,000kg CO_2 equivalent	8×10^{-5} years	1.58
Ozone depletion	1.5kg CFC-11 equivalent	8×10^{-5} years	2522.88
Acidification	7,300 kg SO_2 equivalent	7×10^{-7} years	22.08
Human toxicity	1,200 kg body weight	2×10^{-8} years	0.63

(UNEP-IE, 1996)

Product System
This is part or all of the system being studied by the LCA. It is a collection of material and energy linked processes which perform one or more defined functions.

Proponent
Any individual, government department, authority, industry or association proposing an activity (e.g. project, programme or policy).

Proposal
The development of a project, plan, programme or policy. Proposals can refer to new initiatives or extensions and revisions to existing ones.

Public
Ordinary citizens who have diverse cultural, educational, political and socio-economic characteristics. The public is not a homogeneous and unified group of people with a set of agreed common interests and aims. There is no single public. There are a number of publics, some of whom may emerge at any time during the process depending on their particular concerns and the issues involved.

Role-players
The stakeholders who play a role in the environmental decision-making process. This role is determined by the level of engagement and the objectives set at the outset of the process.

Scoping
The process of determining the spatial and temporal boundaries (i.e. extent) and key issues to be addressed in an environmental assessment. The main purpose of scoping is to focus the environmental assessment on a manageable number of important questions. Scoping should also ensure that only significant issues and reasonable alternatives are examined.

Screening
A decision-making process to determine whether or not a development proposal requires environmental assessment, and if so, what level of assessment is appropriate. Screening is initiated during the early stages of the development of a proposal.

Sensitivity Analysis
This is an analysis to determine the sensitivity of the outcome of the calculation to small changes in the assumptions or to variations in the range in which the assumptions are thought to be valid. The analysis also considers changes in process information.

SETAC
SETAC stands for the "Society of Environmental Toxicology And Chemistry", a professional society, in the form of a non-profit association, established to promote the use of a multi-disciplinary approach to solving problems related to the impact of chemicals and technology on the environment. SETAC provides a neutral meeting ground for scientists working in universities, governments and industry to meet as private individuals (defending no positions or policies) to use the best available science to solve problems. SETAC has taken a leading role in developing the methodology of LCA. More information on SETAC available at http://www.setac.org

Significant/significance
Significance can be differentiated into impact magnitude and impact significance. Impact magnitude is the measurable change (i.e. intensity, duration and likelihood). Impact significance is the value placed on the change by different affected parties (i.e. level of significance and acceptability). It is an anthropocentric concept, which makes use of value judgements and science-based criteria (i.e. biophysical, social and economic). Such judgement reflects the political reality of impact assessment in which significance is translated into public acceptability of impacts.

Stakeholders
A sub-group of the public whose interests may be positively or negatively affected by a proposal or activity and/or who are concerned with a proposal or activity and its consequences. The term therefore includes the proponent, authorities (both the lead authority and other authorities) and all interested and affected parties (I&APs). The principle that environmental consultants and stakeholder engagement practitioners should be independent and unbiased excludes these groups from being considered stakeholders.

Stakeholder engagement
The process of engagement between stakeholders (the proponent, authorities and I&APs) during the planning, assessment, implementation and/or management of proposals or activities. The level of stakeholder engagement varies depending on the nature of the proposal or activity as well as the level of commitment by stakeholders to the process. Stakeholder engagement can therefore be described by a spectrum or continuum of increasing levels of engagement in the decision-making process. The term is considered to be more appropriate than the term "public participation".

Stakeholder engagement practitioner
Individuals or firms whose role it is to act as independent, objective facilitators, mediators, conciliators or arbitrators in the stakeholder engagement process. The principle of independence and objectivity excludes stakeholder engagement practitioners from being considered stakeholders.

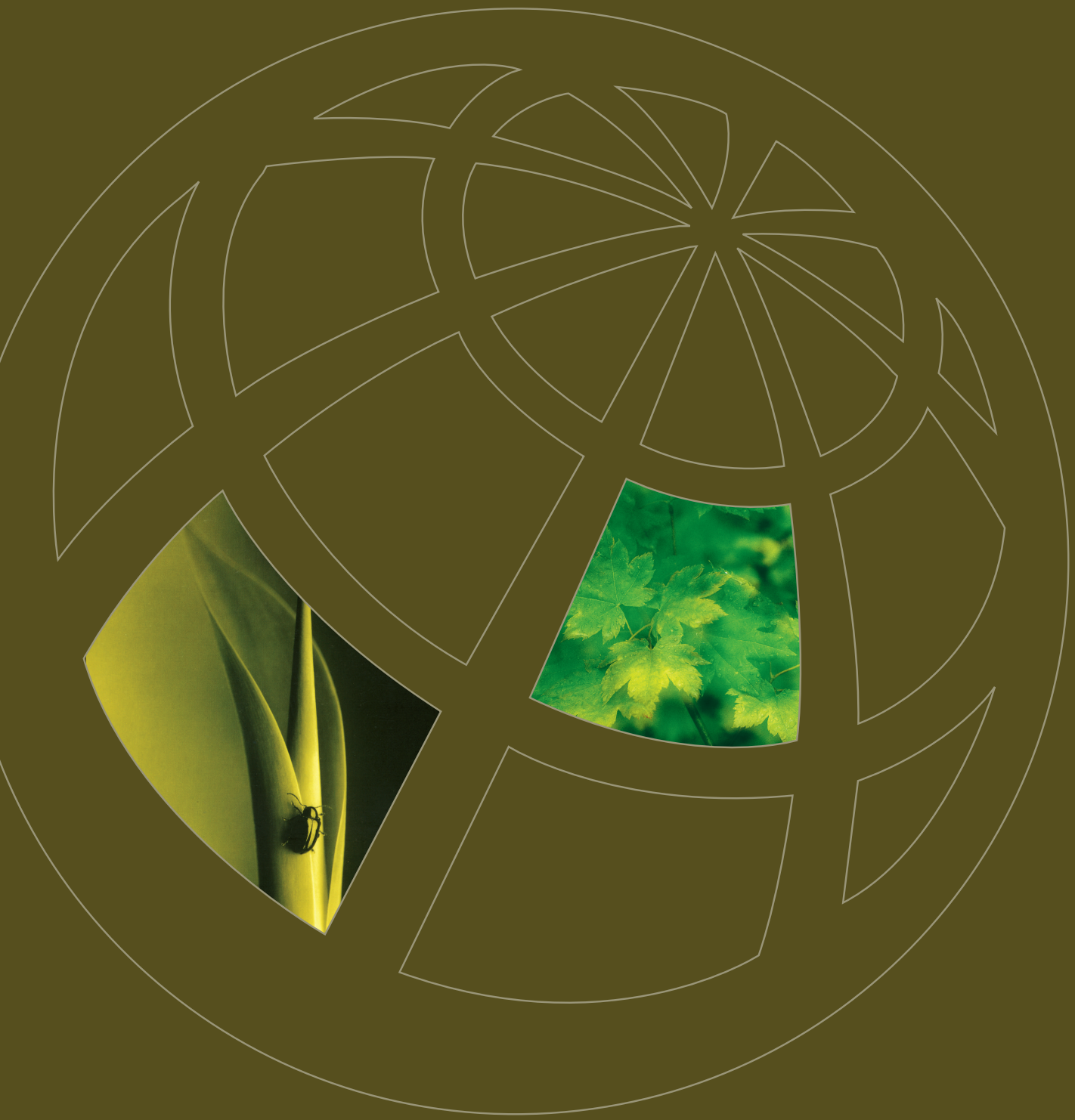
System Boundary
The interface between the product system being studied and the environment or other product systems.

UNEP
UNEP stands for the United Nations Environment Programme and the UNEP Division of Technology, Industry and Economics (UNEP-DTIE), based in Paris, has established, in partnership with SETAC, the Life Cycle Initiative, a project promoting life cycle thinking as a strategy towards the development of a sustainable economy. More information on UNEP-DTIE is available at http://www.unptie.org

Valuation
This is part of the impact assessment where the scores for the different environmental problems are weighted and added up thus creating a single number called the environmental index. This index an be used to compare product alternatives.

ABBREVIATIONS

CBO	Community-based Organization
EA	Environmental Assessment
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EMS	Environmental Management Systems
I&AP	Interested and Affected Party
IEM	Integrated Environmental Management
NGO	Non-governmental Organization
SEA	Strategic Environmental Assessment



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