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Establishing common primary data for environmental overview of product life cycles

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Establishing common primary data for environmental overview of product life cycles

Users, perspectives,
methods, data, and information systems

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Preface

Access to credible, life cycle-based knowledge and information provides a basis for necessary prioritisation and action and also a potential to avoid environmental problems shifting from one phase of the life cycle to another. It also helps to make sure that measures are taken where they will provide the most benefit.

This report describes how information about the environmental performance of products over their life cycles can be accessed anywhere and by any stakeholder throughout the product life cycle.

The report covers different users of environmental product information, various methods and tools used to produce and disseminate that information, and primary data needed for those methods and tools. The report also outlines an information system organisation for potential use as a cooperative approach to supporting stakeholders of product life cycles with environmental information.

The report has been produced as a part of the commission 2004 from the Government to the Swedish Environmental Protection Agency in order to develop information on the environmental impact of products. The aim of the commission is to develop the provision of data, knowledge and information of the environmental impact of products during the whole life cycle. The report is one of the basis to the report to the Government on the commission "Information om produkters miljöbelastning" Swedish EPA report no 5526.

The authors are responsible for the content in the report, why the report cannot be referred to as the Swedish EPA´s position.

Stockholm in December 2005
The Swedish Environmental Protection Agency

Author's preface

This report has been produced by the research group Industrial Environmental Informatics (Industriell Miljöinformatik - IMI) at the Department of Computing Science and Information Technology, Chalmers University of Technology, at the request of the Swedish Environmental Protection Agency (EPA). The commission is one of several assigned to various experts and expert groups as part of a larger project being carried out by the Swedish EPA at the behest of the Swedish Government. The larger project aims to develop information on the environmental impact of products by identifying drivers, obstacles, elements and components of an information system for environmental overview of product life cycles.

A series of international audits of the Swedish competence centre CPM between 1997 and 2004[1,2,3] has recognised the work of the IMI research group as an internationally unique centre of excellence in the field of industrial environmental information management. Within this competence centre the authors have acquired a variety of expertise in the fields of environmental data for product life cycles. In alphabetic order:

Raul Carlson, M.Sc. (Engineering Physics) joined Chalmers in 1995 to participate in the development of SPINE, and later to work as project manager to establish the Swedish national LCA database. He has also been involved in developing the ISO LCA data documentation format ISO/TS 14048, and in European projects on developing DfE methodology for the rail industry and toxicology/LCA methodologies, etc. He has been head of department at IMI since 2001.

Maria Erixon, M.Sc. (Environmental Science) has worked in the field of data and data formats for LCA since 1997, joining Chalmers to work on the CPM database in 1999. Since then she has been engaged in various projects, including a toxicology/LCA database.

Markus Erlandsson, M.Sc. (Engineering Physics) joined the new department of IMI as a systems developer in 2002 and has since worked on DfE tools, eco-procurement tools and web-based LCA tools.

Karolina Flemström, M.Sc. (Chemical Engineering) was also recruited in 2002 to work on establishing a materials database for DfE for the rail industry and has since also been engaged in toxicology/LCA and other databases.

Sandra Häggström, M.Sc. (Chemical Engineering) was recruited in 2003 to develop a materials database for DfE for the rail industry and her work since then includes information management in industrial EMS.

[1] The first international evaluation of CPM was performed in 1997, the second in 2000 and the third in 2004. Only the second two are recognised as available references.

[2] Baras J.S., Frysinger S.P., Graedel T., Lih M.M., Udo de Haes H.A, "International Evaluation Report", CPM Report 2000:8, CPM, Chalmers University of Technology, Gothenburg, Sweden, 2000.

[3] Baras J.S., Frysinger S.P., Inaba A., Stenius P., "CPM International Evaluation Report", CPM Report 2004:2, CPM, Chalmers University of Technology, Gothenburg, Sweden, 2004.

Johan Tivander, M.Sc. (Aquatic and Environmental Engineering) joined the team in 2001 to work as a systems developer, but has also worked on LCA and toxicology data models and software, and has coordinated a large European project in this field.

Raul Carlson, September 2005

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Abstract

This report describes how information about the environmental performance of products over their life cycles can be accessed anywhere and by any stakeholder throughout the product life cycle. Particular consideration has been given to different ways of performing a life cycle assessment (LCA).

The report covers different users of environmental product information, the various methods and tools used to produce and disseminate that information, and the primary data needed for those methods and tools. The report also outlines an information system organisation for potential use as a cooperative approach to supporting stakeholders of product life cycles with environmental information.

Chapter 2 contains a comprehensive (albeit not exhaustive) list of perspectives from which a stakeholder may environmentally view and assess products. A number of examples are given to describe reasons people have in practice for applying each perspective. The intention is to ensure that users find the methods and tools in chapter 3 to be truly relevant.

Chapter 3 lists and presents methods and tools for assessing environmental performance, for acquiring information about environmental impacts, and for providing information on environmental properties of products. Particular emphasis is placed on the different types of LCA that have been identified, how they differ, how to use them, and their differing data requirements.

Chapter 4 lists and presents the data and information that are used or produced by the methods and tools described in Chapter 3. This chapter includes discussion of data availability, data quality issues and data formatting.

Chapter 5 proposes an information system organisation and design taking into account all perspectives and practical needs as described in Chapter 2, as well as all information and data issues described in Chapter 4. Particular attention is paid to the need for compatibility with existing systems, the technical and economic feasibility of building small systems instead of large ones, and the necessity of a short payback time for all investments, particularly those in the private sector.

In chapter 6 the authors present outline recommendations for further work.

Summary

S1 Background

This report shows how data and information about the environmental life cycle performance of products is available and can be made more readily available to stakeholders, including producers, purchasers and private individuals. It also proposes how to organise an information system to make such data available. The specific aim is to describe how the same data can be used for different measures of environmental performance and by different users, to achieve synergies and cost-effectiveness, i.e. how to organise data sources and expertise, and how to format data.

The gap analysis in the report concludes that costly input data are needed to produce valuable output data on the methods and tools for environmental overview of product life cycles, but that insufficient environmental data are available. The cost of acquiring data is high. This is not generally understood by experts, industry and those developing and using methods and tools. There is no common definition of ‘environmental’, so the concept is too wide and databases and information systems are too often built on the basis of specifications that are too broad and unrestricted. The result is that resources are expended and some new knowledge is acquired. But the information system is not optimised for specific users, and it is often costly to attract users to badly designed environmental information systems. Hence, the systems are not used by those who might need them. These are the main problems.

The report lists in detail the types of environmental life cycle information different users request for various reasons, such as energy demand, waste generation, content of toxic substance, recyclability, etc. Much space is devoted to methods related to Life Cycle Assessment (LCA), such as how to perform and acquire data for full LCAs, simplified LCAs and Environmental Product Declarations (EPD), but the report is far from limited to LCA methodology. Environmental Risk Assessment (ERA), material content inventory, Design for Environment (DfE) etc. are also covered in detail.

Since the environmental life cycles of most products are global and involve many industrial sectors, the studies made for this report and the proposals presented are not limited to Europe, for example, or to any specific sector or product category, but are intended to be international and independent of specific sectors.

The authors are experts in the field of industrial environmental information management and have also made extensive literature studies for this report. References are presented as footnotes throughout the report, and there is also a full list of references at the end.

S2 Overview environmental product life cycle performance

Figure S.1 represents a product life cycle and its impact on the natural environment. The drawing is of course much simpler than any a real-life product life cycle; environmental overviews of product life cycles require major simplifications. The simplifications vary, depending on the aspects of environmental performance to be examined.

Simplified rather than full information is often requested for various reporting systems, management systems, methods and tools. Simplifications are named differently depending on the context, e.g. key environmental aspects[4], environmental performance indicators[5], environmental condition indicators[6], category indicators[7], data categories[8], reporting variables[9,10,11], etc. Different choices of environmental indicators are made when evaluating environmental performance of activities, processes, hardware or services[12].

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4 International Organisation for Standardisation (1997), *ISO 14001: Environmental management systems - Specifications with guidance for use.*

5 European Commission (2003), *2003/532/EC, Commission recommendation of 10 July 2003 on guidance for the implementation of Regulation (EC) No 761/2001.*

6 International Organisation for Standardisation (1999), *ISO 14031: Environmental management - Environmental performance evaluation – Guidelines.*

7 International Organisation for Standardisation (2000), *ISO 14042: Environmental management - Life cycle assessment – Life cycle impact assessment.*

8 International Organisation for Standardisation (1997), *ISO 14040: Environmental management - Life cycle assessment - Principles and framework.*

9 Global Reporting Initiative (2002), *Sustainability Reporting Guidelines*, http://www.globalreporting.org/guidelines/2002/gri_2002_guidelines.pdf.

10 Naturvårdsverket (2002), *Planering och utformning av miljöövervakningsprogram*, viewed at http://www.naturvardsverket.se/dokument/mo/hbmo/del1/plan/upplagg4.pdf.

11 World Economic Forum (2005), *2005 Environmental Sustainability Index – Benchmarking National Environmental Stewardship.*

12 Carlson R (2002), *Environmental Performance Indicators*, Published in INSIGHT, Vol 5 Issue 2 July 2002 p. 22-23, The International Council on Systems Engineering (INCOSE).

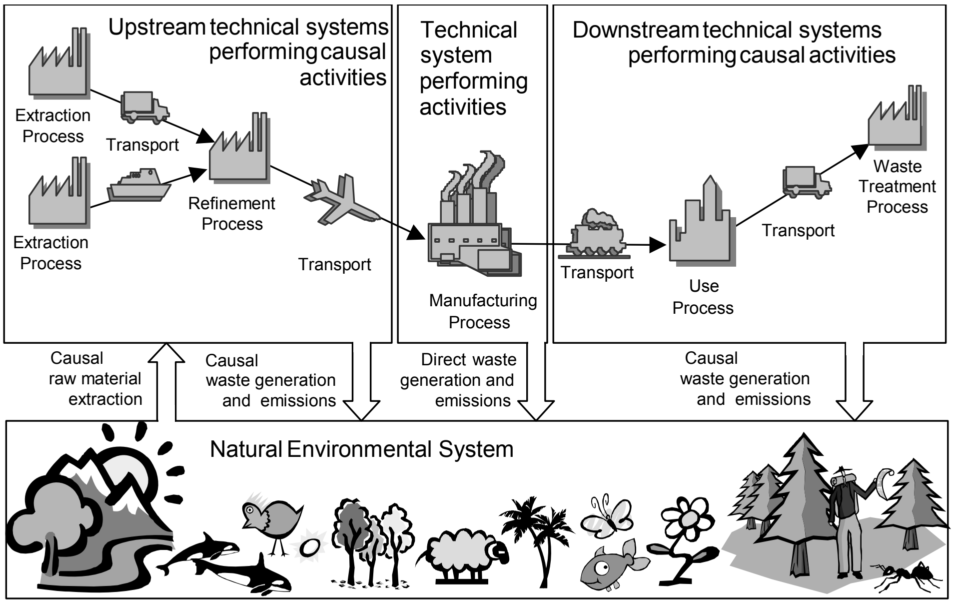

Figure S.1. A schematic product life cycle and its environmental impact.[13] Used with permission. Copyright Raul Carlson and Ann-Christin Pålsson, CPM, Chalmers University of Technology, 1998

It is difficult to identify indicators so they are significant, understandable, and so the cost of acquiring the primary data needed and collating the simple information are acceptable[14], [15]. Many organisations throughout the world (e.g. ISO, OECD, EU, GRI, WEF and WBCSD) are developing and selecting good and representative parameters for defining environmental indicators[16].

The content and layout of this report is based on the contention that complex environmental information does not suffice to provide people in general with an environmental overview of product life cycles, and that simplified environmental information, such as environmental indicators, must be used instead. The report therefore starts by examining the needs expressed by users.

S3 Users

Everyone is a potential user of environmental information. But if this report is to make a practical contribution, its scope must be limited. Since global commitment to sustainable development is well recognised under Agenda 21[17], that international agreement forms a natural basis for delimitation. The use of environmental information is intended for sustainable development, and the users of environmental

[13] Carlson R, Pålsson A-C (1998), *Maintaining Data Quality within Industrial Environmental Information Systems*; 12 th International Symposium 'Computer Science for Environmental Protection' Bremen 1998; Band 1/Volume 1 p. 252-265

[14] Flemström K (2003), *Environmental Performance Indicator (EPI), Methodology in REPID*, Chalmers University of Technology, Sweden.

[15] Carlson, Tivander, Erixon et al. (2004), *Conceptual model report,* OMNIITOX project report 2004, www.omniitox.net.

[16] General environmental indicator links can be found at: http://www.pepps.fsu.edu/EI_Gen.html

[17] UN (1992), *Agenda 21*, available at http://www.un.org/esa/sustdev/documents/agenda21.

information intend to take decisions furthering that development, i.e. by improving the environmental performance of product life cycles

Figure S.2 describes the general use of environmental information, in that there is a vision of a sustainable industrial society, and people control the environmental impact of product life cycles by the various decisions they make. If the decision maker is provided with environmental information about the consequences of his decisions, he may be in a position to take more responsible control.

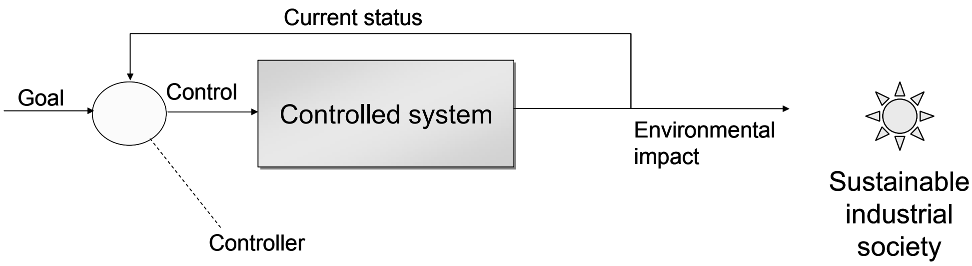

Figure S.2 The diagram shows that to navigate towards sustainable development controllers or decision makers need to understand the system they control and need feedback on consequences as well as visionary and short-term objectives. Copyright Carlson R. and Pålsson A-C, CPM, Chalmers University of Technology, 1998. Used with permission.

There may be many situations or reasons why people request environmental information. This report selects five specific reasons as a basis for the analyses, recommendations and proposals that follow throughout the report:

- *Purchasing products*; to assess a product in terms of becoming an owner of a product or facility, for example.
- *Designing products*; to assess a product in terms of being able to improve its design.
- *Analysing product content*; to asses the material contents of a product so as to gain an overview of the environmental consequences of choices of materials.
- *Considering product risks*; to assess a product in terms of its risks or ability to cause harm over its life cycle.
- *Societal consequence of product*; to assess a product based on the environmental consequences of large-scale production of the product.

The report gives many examples of each of these uses of environmental information from all over the world and in numerous sectors. However, information requirements may vary greatly, depending on the user. To provide a structure to these differences, four user categories for environmental information are defined on the basis of the reference material: (i) environmental scientists and experts; (ii) policy makers of various kinds; (iii) professional decision makers; and (iv) laymen in their everyday actions. These user categories are independent of industrial sector and product type.

These users have widely differing requirements of information, and use it in different ways. Environmental scientists and experts tend to request highly detailed facts and use the information to produce new knowledge. Policy makers also request detailed information but in condensed form, and use it to define rules and set frameworks for action. Hence, both these user categories produce new information rather than taking direct decisions about the physical world. Professional and lay decision makers use the information to make decisions on hardware and physical consequences, such as purchase of goods and services.

When the four user categories are seen in the light of Figure S.2, it may be concluded that this report is mainly directed towards the day-to-day information needs of professional and lay decision makers. To be precise, these user categories need simple information of various kinds, as described in the previous section "S2 Overview environmental product life cycle performance".

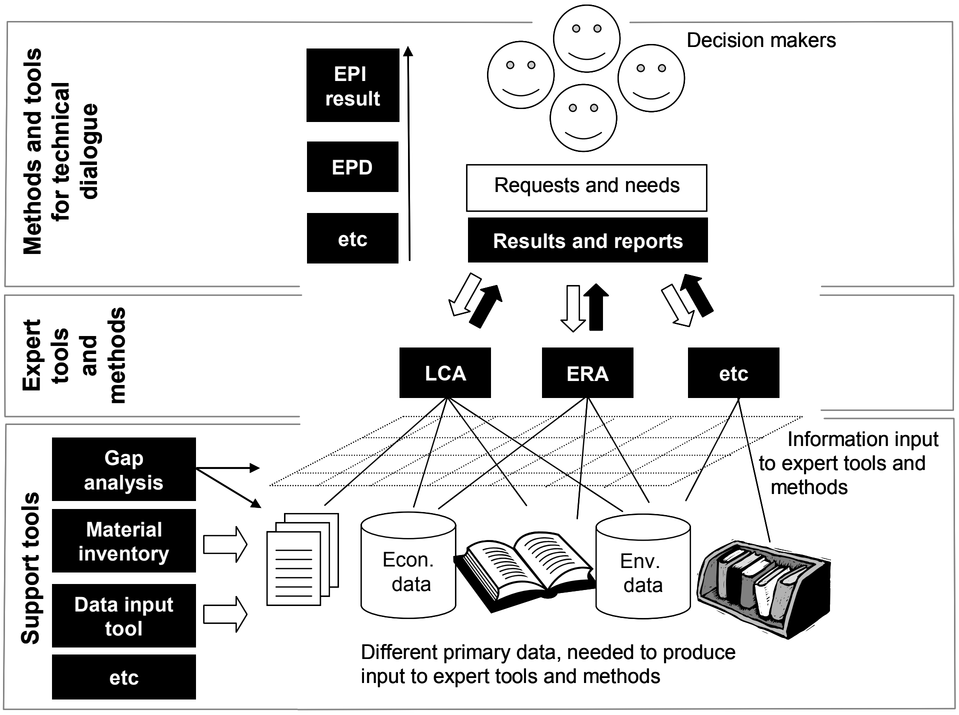

Figure S.3. The tools are classified according to their intended use: support tools, expert tools and communication tools. Expert tools and methods deal with the requests and needs of decision makers. Support tools give information input for the expert tools. The methods and tools for technical dialogue are used to make the results from the expert tools understandable for decision makers.

S4 Methods and tools

To obtain simple environmental indicators, detailed primary data first need to be compiled and aggregated using various methods and tools in sequence: Measurements or modelling produces low level primary data, which are then compiled to form emission data, toxicity data, environmental impact data, for example. These data may be used for an LCA method or tool according to ISO standards, and the results of that study may be recompiled to produce an environmental product declaration or a weighted life cycle indicator according to a chosen impact assessment method.

This sequential use of methods and tools is shown in Figure S.3, where the decision makers are end users of various simple results produced by methods and tools intended for communication of LCA results, for example. The sequence of methods and tools requires a large number of support tools to acquire and process the data, such as databases, gap analysis methods, product material inventory procedures and various data input tools.

LCA and ERA are regarded as expert tools, and they are not intended to produce information immediately useful to decision makers. This means, for example, that simplified LCAs should not be regarded as easy to understand, only easy to use. However, there are many ways of simplifying LCA, ranging from general LCI databases, simple full LCA software, prefabricated cradle-to-gate and end-of-life databases for specific types of product, use of available statistics by I/O-analysis, communication via EPD systems, simplified screening LCAs, etc. There are also methods where the entire LCA is shown only as environmental product life cycle indicators, easy to use and easy to understand for the decision maker. It must be stressed that a full LCA is also a substantial simplification, since it both limits and structures the work required to obtain a life cycle overview.

The general recommendation about how to use various simplified methods and tools, and specifically LCA methods and tools, is that simplification should be in line with the user's needs. For example; a full LCA is a good way of supporting and simplifying systematic accumulation of new knowledge of the environmental life cycle of a product or a decision. Simple LCA tools such as software or screening tools are useful within organisations where the users can be sure that the background information and simplified methodology are right for their purpose within the organisation. Examples are design and purchasing departments. Both full LCAs and simplified LCAs are difficult to communicate to people who have not participated in use of the method or tool. LCA tools based on I/O methodology are practical since they can make use of publicly available statistical data. The major weakness is that they are not as intuitively understood as LCAs. LCAs are easy to understand for anyone, even though performing a full LCA is hard work. National statistics and I/O analyses are complex concepts that may be difficult to grasp.

Hence, simplified methods and tools such as LCAs are useful if the right simplification is chosen for the right situation. This is equally relevant for small and medium-sized enterprises (SMEs), large corporations, countries or international cooperation. SMEs should seek to use methods and tools that are easy to use, interpret and communicate and should share costs with other SMEs or larger corporations, for example. Publicly funded initiatives and large corporations should seek structured ways of sharing data and information, perhaps by striving to harmonise environmental performance indicators.

S5 Data, availability and information systems

Figure S.2 shows that primary data on current status needs to be communicated as environmental information to decision maker and be updated at appropriate intervals. Some methods and tools very seldom update current status. For example, LCI databases and LC impact assessment methods are often not updated at all, or at intervals of 5 to 10 years. Common EMS systems update current status at least once a year in the annual environmental report. However often they are updated, methods and tools for environmental overview of product life cycles cannot be simplified beyond a need for primary data.

Primary environmental data is expensive. It is needed in large quantities, about many materials, many emissions, many products, many production facilities, many geographical locations and many different environmental conditions. There are major financial advantages in coordinating primary environmental data acquisition, and in sharing the same data sources. Hence, establishing common primary data for an environmental overview of product life cycles is a key economic strategy for sustainable development in general, and for every local environmental management system at production plants and in communities, enterprises, countries and international cooperation.

This report describes how a common format for primary data for a wide variety of methods and tools may be structured. The format allows sharing of data for LCA, ERA, EMS, DfE, etc. The report also lists many available primary data sources that may be used to provide data for the many different methods and tools. To better understand why these existing data sources are not enough for all needs, the concept of data availability is examined systematically, by introducing six dimensions of availability:

- *Existence* - whether anyone has ever structured this specific type of data.
- *Coverage* - the extent to which the data covers the exact needs.
- *Understandability* - whether the data is documented so that it can be interpreted by a user.
- *Maintenance* - whether there is anyone to contact to obtain more information about the data.
- *Accessibility* - whether the data is actually accessible from the perspective of the user in terms of cost, confidentiality, etc.
- *Formatting* - whether the data is separated in specified data fields in the documentation, or whether it is available only in free text in literature or structured in databases.

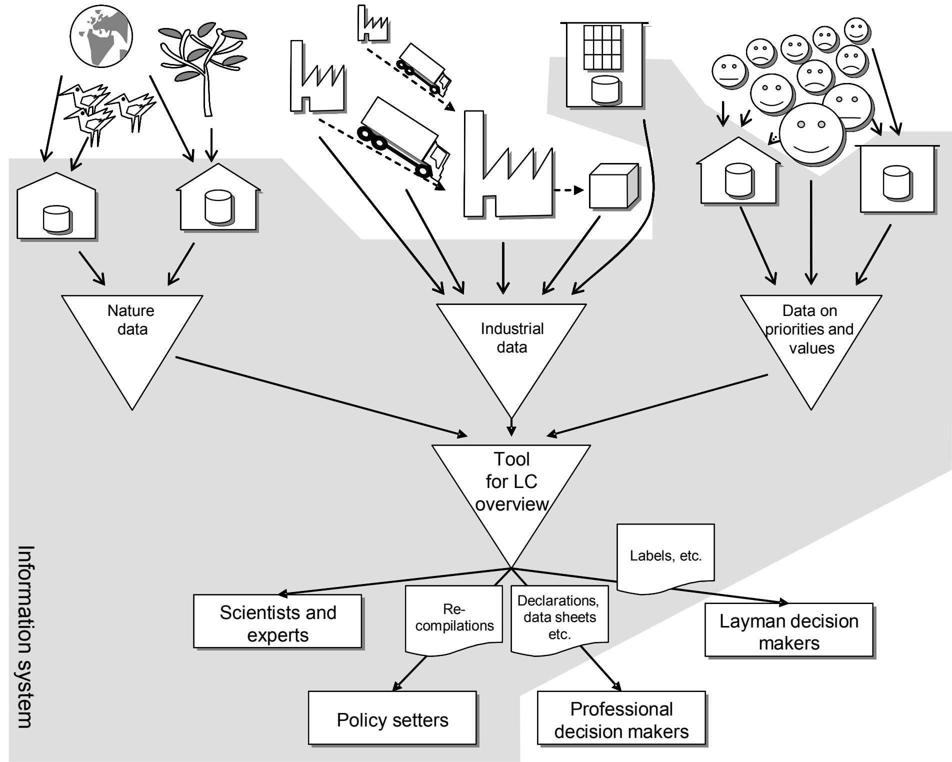

Figure S.4 A simplified overview of the organisation of an information system for environmental overview of product life cycles anywhere in society.

Figure S.4 depicts an organisation of available data sources, methods and tools and the various user categories addressed in section 'S3 Users'. This organisation of primary data, methods, tools and users is an information system. There are no limitations on the geographical location or geographical distribution of the information system. It is assumed that the various data sources are located at different places throughout the world, around the raw material abstraction sites, transport routes and production facilities associated with the life cycle of a product. It is worth reiterating that the information may be updated at very infrequent intervals, and that the information is dealt with in sequence.

This organisation of data sources and other resources into an information system is described in detail in the report, so as to present the key issues in making data available for environmental overview of product life cycles. Coordination of data and information needs is important, as is the use of a common format and a common overall strategy. This will also be addressed in the recommendations in the next section.

S6 Recommendations

As was pointed out in section 'S3 Users', professional and lay decision makers are the most important users of the information system. But those users have little interest in the full concept of environmental responsibilities and sustainable development. Their focus is on decisions. The responsibility for establishing an information system needs to lie in the hands of political and proactive proponents and stakeholders. The following recommendations from the authors of this report are intended for those proponents and stakeholders.

Scope the purpose of the information

Environmental information can be made available in many ways, but if that information is to be made more readily available in practice, it is important to clearly identify the intended user of the information, how the information is to be used and for what purpose. See section 'S3 Users'.

Establish and harmonise product life cycle indicators

Section 'S2 Overview environmental product life cycle performance' introduced environmental indicators to denote simple environmental information. When indicators mean the same thing to different people they can be understood, communicated, used for comparison and improvements, etc. This is one reason to harmonise indicators.

The other reason to harmonise indicators is the immense amount of primary data needed to produce the condensed information for an environmental product life cycle indicator. Data availability may be improved if the same primary data are requested by many users for many applications, so that the resources used to acquire data are not fragmented, and a steady data demand is built up instead.

Examples of ongoing initiatives:

- UNEP/SETAC Life Cycle Initiative[18], whose aim is to put life cycle thinking into practice and improve the supporting tools by means of better data and indicators
- COST Action 530[19], where the goal is to bridge the gap between fundamental LCA research and the needs of industry for an operational framework and model.
- The Eco Procurement board introduced which maintains agreements within the railway sector.
- The CASCADE[20] project, where formats for environmental data have been integrated with existing and established standards for storage and exchange of material and product data[21,22] used in other engineering disciplines. The project also provides a solution for how nomenclatures can be maintained at different organisational levels.

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18 UNEP/SETAC Life Cycle Initiative, http://www.uneptie.org/pc/sustain/lcinitiative/home.htm.
19 COST Action 530, www.empa.ch/cost530.
20 CASCADE, http://192.107.71.126/cascade.
21 International Organisation for Standardisation, ISO 15926 Integration of life-cycle data for process plants including oil and gas production facilities.
22 International Organisation for Standardisation, ISO 10303-235 Materials information for product design and validation (under development).

Provide support concerning methods and tools

GENERAL
A large number of methods and tools are available for simplifying environmental overview of product life cycles, but most tools face substantial data availability gaps. Many of the requested methods and tools exist, but the intended users are unlikely to find the most appropriate tool themselves without substantial expert assistance. It is recommended that user needs and existing methods and tools be better matched.

It is also recommended that the methods and tools should provide users and decision makers with meaningful environmental indicators, and that different simplifications are made for different users, depending on their identity and task.

LIFE CYCLE ASSESSMENT
First of all, it should be stressed that a full LCA in accordance with the ISO 14040-series (for instance) is a substantial simplification, since it both limits and structures the work effort to acquire a life cycle overview. Whatever the number of processes surveyed and whatever the number of inventory parameters, impact categories or category indicators, a full LCA will still just provide a simplified environmental product life cycle overview.

Since there are many ways of simplifying an LCA, it is recommended that the meaning of simplified life cycle assessment or simplified environmental overview product life cycles should be discussed more systematically. There are many simplifications to be made regarding data acquisition, level of detail, communication of results, use of results, or tools for making complex LCAs. Hence, 'simplified LCA' is too vague a concept.

It is recommended that the use of harmonised environmental product life cycle indicators be distinguished from discussion of LCA methodology and tools.

Increased availability of data and information

There are four aspects to be considered to establish common primary data for environmental overview of product life cycles:

1. Focus on the users and applications for which data should be made available. It is impossible to solve the problem generally.
2. Identify the primary data needed to produce the information requested by and for the intended users and applications.
3. Structure the identified primary data in a general format so that all the methods and tools can share the same primary data sources.
4. Establish a strategic build-up of all necessary primary data, which must be based on well-defined environmental product life cycle indicators.

It is recommended that long-term decisions be taken to ensure that data is available for a number of environmental product life cycle indicators significant for global, regional and local environment throughout the world, and for sustainability for future generations. These long term environmental indicators should be fixed at different strategic levels, such as by the UN and World Bank, by the USA, EU and other regional unions of countries and states, at national level, in industrial sectors and in public procurement and consumption. Indicators should be set to serve as long-term targets to drive action plans towards improved data availability. Cooperation should be established and expertise should be made available to support synergetic definitions of indicators, so that primary data sources and expertise serve as many purposes and applications as possible.

Since most primary environmental data sources are established on the basis of ad hoc principles for a specific purpose with little or no information system contexts, and most data sources are incompatible at all levels: technically, conceptually and semantically. It is recommended that international standardisation efforts be supported, so that concepts, terms, common data formats and nomenclatures can be designed to integrate data and information in various systems.

Information system design

International, regional and national cooperation should be established to organise an information system by practical means, e.g. by coordinating competence and supporting harmonisation and standards. It is also recommended that this work be based on a long-term strategy, and that competence capacity be built up via knowledge centres, data generators and maintainers, for example. Dedicated capacity of this kind should be assigned to support and work with companies, consultants and software vendors to build up international, sector-independent and interdisciplinary coordination. A combination of business models and defined responsibilities should also be used to focus on supplying environmental information to decision-makers throughout product life cycles.

Clear vision and decisive policies on the part of governmental, industrial and non-governmental leaders will be needed to establish this information system. It is therefore strongly recommended that the proponents and the stakeholders of environmental information assume joint responsibility for an overall environmental information system.

S7 Initial steps

Introduction

In this section the authors recommend the first steps in improving data availability for environmental overview of product life cycles by establishing common primary data. These recommendations need not be adopted in the order proposed here. The steps should be formulated and implemented to enhance the strategic dimension, increase knowledge, achieve geographical dissemination and to permeate society. It is also anticipated that the absolute mandate of the board may increase over time, with appropriately limited mandates during the initial phase of implementation. A natural starting point is to conduct limited pilot projects in business sectors, or at national or regional level.

Step 1: Policy and competence

The first step is to designate policy makers and establish a responsible board and competence base.

COLLABORATIVE BOARD

Set up a collaborative board (or network or association) of proponents and stakeholders in order to develop rational information systems. The board should be willing to take charge and create visions and strategies. The board should establish an information feedback relationship with both professional and lay decision makers.

The board could play a key role in prioritising between tasks, maintaining the strategy, and establishing and securing long-term funding through relations with funding financing institutions and banks. It could also establish, pursue and maintain necessary standards.

The long-term goal of the board should be to establish and maintain international collaboration between EPAs, the boards of multinational corporations and the academic elite in related fields. The strategy of the board should be to carry out inter-organisational programmes of practical and well-defined problem-solving/gap-bridging projects e.g. defining a specific indicator, exporting a specific database to common formats, starting a database of specific primary data. The board should also distinguish research from implementation by delegating implementation responsibilities to economically sustainable and sound businesses. Research issues must be quickly identified and presented to a strategic academic reference group. Research funding within this domain must be based on problem solving.

There are similarities between the UNEP/SETAC LC Initiative, for example, and this collaborative board, but the differences are that this board

- focuses on simple information for environmental overview of product life cycles for end users, regardless of whether LCA is the method or not;
- considers providing simple information for end users as the primary objective and methods and tools as secondary, while the UNEP/SETAC LC Initiative has emerged from the methodological point of view adopted by the method developers;
- stresses primary data as the basis for all other information. Acquisition and availability of primary data is not part of the UNEP/SETAC LC Initiative, only highly aggregated LCA data and databases.

In the first place, the work should be carried out within the framework of existing organiations, such as the EU:s Joint Research Center and ISO.

KNOWLEDGE CENTRES

Establish knowledge centres around already existing competence units, selected on criteria such as experience, practical value of the specific skills, potential to grow in the direction of strategic needs, etc. International cooperation and competence sharing between knowledge centres should be promoted to provide further impetus to the harmonisation processes as well as the sharing of expertise and experience.

Step 2: Scope and format

The collaborative board could define scope in terms of which users to address, which applications to consider and which indicators to use to describe environmental overview of product life cycles. On the basis of these decisions a common data format can be developed for exchange of data between data sources and methods and tools. The format may be developed by experts assigned to the task at the knowledge centres, and it should be developed jointly with tool developers and data source maintainers. The data format should

- suit all the primary data needed by the intended users;
- be based on a general level of primary data;
- allow for relevant documentation;
- be non-redundant, i.e. economical and efficient.

Step 3: Infrastructure and information system

On the basis of the indicators selected and defined, the use of the common format to establish infrastructures and communication channels to share data from sources to (first) professional and (then) lay decision makers should be developed. This will entail a great deal of cooperation between data source maintainers, tools developers and informatics experts.

The data source maintainers should be supported as needed, so they can provide the necessary primary data and establish publication routines. Skills needed to aggregate primary data into layers of semi-simple data will also be valuable. These skills are possessed by risk analysts, ecologists, LCA consultants and others. It will also be necessary to find ways of encouraging other providers of information, methods and tools, as well as experts in relevant fields, such as policy makers, data publishers, software developers to develop PCRs, product design criteria, eco-procurement criteria etc.

The result should be a complete mapping of the information system, similar to Figure S.4, for a specific category of users, a specific application and a specific indicator. Each component or module is recognised and each gap is identified.

Step 4: Generate new data and maintain knowledge

The board should identify international industries, countries and financiers willing to complete and maintain full life cycle overviews, to improve and maintain data availability and knowledge.

Step 5 and ahead

The board should specify improvement needs and focus on eliminating a few prioritised obstacles at a time. The board should allow short time frames for completing projects and constantly assess whether practical success has been achieved. Flexibility, pragmatism and practical achievement are the key to the success of this board, combined with collaboration, consensus and coordination.

Hence, establishing common primary data for environmental overview of product life cycles is a practical process, which can be achieved by determination and successive improvements.

Sammanfattning

S1 Bakgrund

Denna rapport beskriver tillgång till data och information om miljöpåverkan av produkter ur ett livscykelperspektiv och hur de kan göras tillgängliga för berörda intressenter i samhället såsom producenter, upphandlare och medborgare samt ger förslag på hur ett sådant informationssystem för datatillgång skall läggas upp. Syftet är att beskriva hur samma data kan användas av flera användare för olika mätningar av miljöpåverkan samt för att uppnå samordningsfördelar och kostnadseffektivitet, dvs. hur olika datakällor och expertis skall organiseras och hur data skall formateras.

Av rapportens ”gap-analys” framgår att metoder och verktyg för en miljöbedömning av produkters livscykler, kräver kostsamma input-data för att få fram viktiga output-data, men alltför få miljödata finns att tillgå. Kostnaden för insamling av data är hög. Förståelsen för detta är liten hos experter inom industrin och hos utvecklare och användare av metoder och verktyg. Det finns ingen gemensam definition för ”miljöpåverkan”, konceptet är för brett och databaser och informationssystem är därför ofta uppbyggda med en alltför bred och fri specifikation. Resultatet har blivit att resurserna ändå spenderas, men liten ny kunskap förvärvas. Informationssystemet är inte optimerat för specifika användare och det blir ofta dyrt att attrahera användare till dåligt uppbyggda miljöinformationssystem. Systemen används kanske därför inte av dem som har behov av dem. Dessa är de huvudsakliga problemen.

Rapporten innehåller en detaljerad lista över vilka typer av information om produkters miljöpåverkan i ett livscykelperspektiv som olika användare behöver, som t.ex. energibehov, generering av avfall, toxiskt innehåll, möjlighet till återvinning etc. Metoder för livscykelanalys (LCA) ges stort utrymme, t.ex. hur skall sammanställning och förvärv av data för fulla LCAs, förenklade LCAs och miljövarudeklarationer (EPD) gå till, men rapporten är långt ifrån begränsad till enbart LCA-metoder. Även redogörelser för miljöriskbedömning (ERA), inventering av materialinnehåll, design för miljö (DfE) etc. ingår.

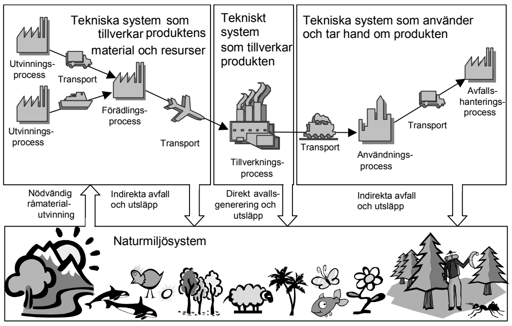
Eftersom de flesta produkters miljöpåverkan under livscykeln är global och omfattar många industrisektorer, är inte de studier som gjorts för denna rapport och de förslag som lagts fram, begränsade till enbart Europa eller någon specifik sektor eller produktkategori utan är avsedda att vara internationella och sektoroberoende.

Författarna är experter inom området hantering av industrimiljöinformation och har även utfört omfattande litteraturstudier för denna rapport. Referenserna återfinns som fotnoter genom hela rapporten samt i en komplett referenslista i slutet av rapporten.

S2 Miljöbedömning av produkters livscykler

Figur S.1 visar en produkts livscykel och hur den påverkar miljön. Figuren ger naturligtvis en förenklad bild av en verklig produkts livscykel; en miljöbedömning av produkters livscykler måste baseras på förenklingar. Förenklingarna måste varieras med hänsyn till olika syften och vilka aspekter av miljöprestanda som är av intresse.

I många fall föredras förenklad information i stället för en mer fullständig för olika rapporteringssystem, ledningssystem, metoder och verktyg. Förenklingarna ges olika beteckningar i skilda sammanhang, såsom signifikanta miljöaspekter[23], miljöprestandaindikatorer[24], miljökonditionsindikatorer[25], kategoriindikatorer[26], datakategorier[27], rapporteringsvariabler[28,29,30] etc. Olika miljöindikatorer används för utvärdering av miljöpåverkan av verksamheter, processer, hårdvara eller tjänster[31].



Figur S.1. En schematisk bild av produkters miljöpåverkan under livscykeln[32]. Används med tillstånd. Copyright Raul Carlson och Ann-Christin Pålsson, CPM, Chalmers Tekniska Högskola 1998

Det är svårt att identifiera indikatorer så att de blir signifikanta och begripliga och att kostnaden för anskaffning av nödvändiga underlagsdata och sammanställning av den enkla informationen blir godtagbar[33,34]. Arbete med att utveckla och välja ut

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[23] International Organization of Standardization (1997), *ISO 14001: Environmental management systems - Specifications with guidance for use*

[24] European Commission (2003), *2003/532/EC, Commission recommendation of 10 July 2003 on guidance for the implementation of Regulation (EC) No 761/2001*

[25] International Organization of Standardization (1999), *ISO 14031: Environmental management - Environmental performance evaluation – Guidelines*

[26] International Organization of Standardization (2000), *ISO 14042: Environmental management - Life cycle assessment – Life cycle impact assessment*

[27] International Organization of Standardization (1997), *ISO 14040: Environmental management - Life cycle assessment - Principles and framework*

[28] Global Reporting Initiative (2002), *Sustainability Reporting Guidelines*, http://www.globalreporting.org/guidelines/2002/gri_2002_guidelines.pdf

[29] Naturvårdsverket (2002), *Planering och utformning av miljööervakningsprogram*, viewed at http://www.naturvardsverket.se/dokument/mo/hbmo/del1/plan/upplagg4.pdf

[30] World Economic Forum (2005), *2005 Environmental Sustainability Index – Benchmarking National Environmental Stewardship*

[31] Carlson R (2002), *Environmental Performance Indicators*, Published in INSIGHT, Vol 5 Issue 2 July 2002 p. 22-23, The International Council on Systems Engineering (INCOSE)

[32] Carlson R, Pålsson A-C (1998), *Maintaining Data Quality within Industrial Environmental Information Systems*; 12th International Symposium 'Computer Science for Environmental Protection' Bremen 1998; Band 1/Volume 1 p. 252-265

[33] Flemström K (2003), *Environmental Performance Indicator (EPI), Methodology in REPID*, Chalmers Tekniska Högskola, Sverige

[34] Carlson, Tivander, Erixon et al. (2004), *Conceptual model report,* OMNIITOX project report 2004, www.omniitox.net

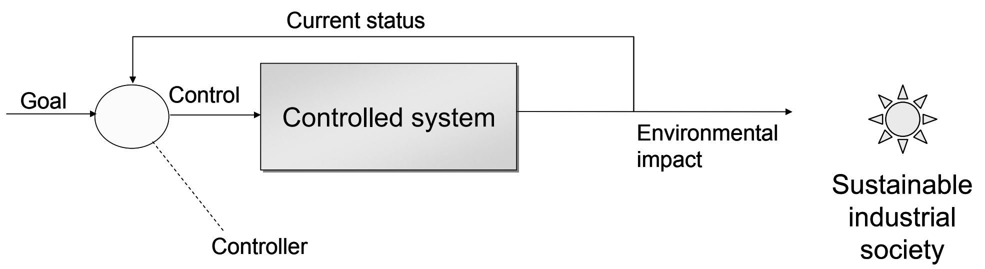
bra och representativa indikatorer för att definiera miljöindikatorer[35] pågår inom många organisationer världen över, t.ex. inom ISO, OECD, EU, GRI, WEF och WBCSD.

Innehållet och utformningen av denna rapport bygger på idén att komplex miljöinformation inte är tillräcklig för att ge allmänheten information om produkters miljöpåverkan ur ett livscykelperspektiv, i stället måste förenklad miljöinformation som t.ex. miljöindikatorer, användas. Samråd med olika användare om deras behov och krav ligger därför till grund för denna rapport.

S3 Användare

Alla är potentiella användare av miljöinformation. För att rapporten skall tjäna ett praktiskt syfte måste dess omfattning begränsas. Eftersom det internationella åtagandet för hållbar utveckling är väl känt genom Agenda 21[36], är denna internationella överenskommelse en naturlig utgångspunkt för att begränsa omfattningen. Användningen av miljöinformation syftar till hållbar utveckling och användare av miljöinformationen strävar efter att fatta beslut som främjar sådan utveckling, dvs. som förbättrar den miljömässiga påverkan av produkternas livscykel.

Figur S.2 beskriver den generella användningen av miljöinformation för att ge en vision om ett hållbart industrisamhälle så att människor genom olika beslut kan kontrollera produkters miljöpåverkan genom livscykeln. Om beslutsfattaren får tillgång till miljöinformation om konsekvenserna av sina beslut, kanske han kan ta ett större ansvar.



Figur S.2 En schematisk bild som visar att kontrollanter och beslutsfattare måste förstå det system de kontrollerar, för att kunna navigera mot en hållbar utveckling. De behöver också feedback om konsekvenser samt både visionära och kortsiktiga mål. Copyright Carlson R. och Pålsson A-C, CPM, Chalmers Tekniska Högskola, 1998. Använd med tillstånd.

Det kan finnas flera olika skäl till att begära miljöinformation och i denna rapport har vi valt ut fem specifika skäl som bas för de analyser, rekommendationer och förslag som ingår i rapporten;

- *Köp av produkter*; att bedöma en produkt från utgångspunkten att bli ägare av exempelvis en produkt eller anordning.
- *Design av produkter*; att bedöma en produkts design med utgångspunkt i hur den kan förbättras.

[35] General environmental indicator links can be found at: http://www.pepps.fsu.edu/EI_Gen.html
[36] UN (1992), *Agenda 21*, available at http://www.un.org/esa/sustdev/documents/agenda21

- *Analysera innehållet i en produkt*; att bedöma en produkts materialinnehåll med hänsyn till materialens konsekvenser för miljön.
- *Bedöma risker med produkter*; att bedöma en produkt ur potentiell risksynpunkt eller dess förmåga att orsaka skada under livscykeln.
- *Produkters konsekvenser för samhället;* att bedöma en produkt baserat på miljöpåverkan från storskalig framställning av produkten.

Rapporten ger många exempel på dessa användningsområden av miljöinformation från hela världen och en mängd olika sektorer. Beroende på vem användaren är, kan emellertid informationsbehov och krav vara mycket olika. För att strukturera dessa skillnader, definieras fyra användarkategorier av miljöinformation baserat på referensmaterial; miljöforskare och experter, politiska ledare av olika slag, professionella beslutsfattare och lekmän i deras dagliga verksamhet. Användarkategorierna har valts ut för att vara oberoende av industrisektor och produkttyp.

Alla dessa användare av miljöinformation har varierande krav på information och använder den på olika sätt; miljöforskare och experter kräver t.ex. mycket detaljerade fakta och använder informationen för att ta fram nya kunskaper. Politiska ledare behöver också detaljerad information men i lättanvänd form, för att kunna definiera regler och sätta upp ramar för åtgärder. Båda dessa användarkategorier producerar således ny information i stället för att fatta direkta beslut om den fysiska världen. Professionella och övriga beslutsfattare använder informationen som underlag vid beslut om hårdvara och de fysiska konsekvenserna av inköp av varor och tjänster.

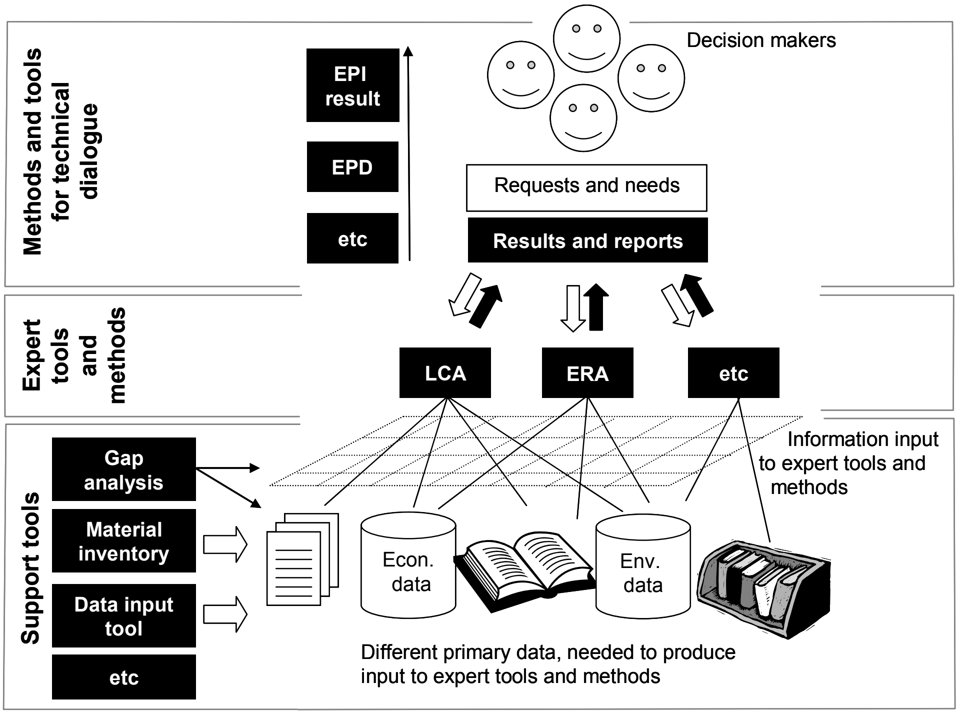
Genom att kombinera de fyra användarkategorierna med figur S.2, framgår att denna rapport huvudsakligen riktar sig till professionella beslutsfattare och lekmän i beslutsfattande ställning, för att tillgodose deras behov av information i den dagliga verksamheten. Speciellt dessa användarkategorier behöver enkel information av olika slag, såsom beskrivs i ovanstående sektion ”S2 miljöbedömning av produkters livscykler”.

S4 Metoder och verktyg

För att ta fram enkla miljöindikatorer måste först detaljerade underlagsdata samlas in och sammanställas med hjälp av olika metoder och verktyg. Mätningar eller modelleringar ger underlagsdata på låg nivå, vilka sedan sammanställs till exempelvis utsläpps-, toxicitets- och miljökonsekvensdata etc. Dessa data kan användas med t.ex. en LCA-metod eller verktyg enligt ISO standarder och studiens resultat kan sammanställas till exempelvis en miljöproduktdeklaration eller en viktad livscykelindikator enligt någon metod för bedömning av påverkan.

Användning av metoder och verktyg enligt denna ordning visas i figur S.3, där beslutsfattarna är slutanvändare av olika enkla resultat som erhållits med metoder och verktyg avsedda för kommunikation av t.ex. LCA-resultat. I den löpande kedjan av metoder och verktyg finns behov av ett stort antal stödverktyg för att samla in och behandla data, såsom databaser, metoder för gap-analys, rutiner för inventering av produktmaterial och olika datainmatningsverktyg.

LCA och ERA betraktas som expertverktyg och är inte avsedda att ge direkt användbar information till beslutsfattare. Det betyder t.ex. att förenklade LCAs inte skall ses som lätta att förstå utan endast lätta att använda. Det finns emellertid många sätt att förenkla LCA, från allmänt uppbyggda LCI databaser, enkel komplett LCA-mjukvara, pre-fab cradle-to-gate samt databaser med utgångna produkttyper, användning av redan tillgänglig statistik med I/O-analys, kommunikation via EPD system, förenklade screening LCAs etc. Det finns även metoder där hela LCA enbart visas som miljöindikatorer för en produkts livscykel, som är lätta att använda och förstå för beslutsfattare. Det bör understrykas att även en fullständig LCA är en väsentlig förenkling, eftersom den både begränsar och strukturerar arbetsinsatsen för att göra en livscykelbedömning.



Figur S.3. Verktygen är grupperade efter deras avsedda användning; stödverktyg, expertverktyg och kommunikationsverktyg. Expertverktyg och metoder ger svar på beslutsfattarnas frågor och behov. Stödverktygen matar in information till expertverktygen. Metoder och verktyg för teknisk dialog används för att göra resultaten från expertverktygen begripliga för beslutsfattarna.

Den allmänna rekommendationen för hur olika förenklade metoder och verktyg skall användas, speciellt LCA-metoder och verktyg, baseras på att förenklingen skall anpassas till användarens behov. Exempelvis, är en fullständig LCA en bra metod för att stödja och förenkla en strukturerad uppbyggnad av ny kunskap om en produkts eller ett besluts miljölivscykel. Enkla LCA-verktyg som mjukvara eller screening-verktyg, kan tillämpas inom organisationer där användare kan lita på att bakgrundsinformationen och den förenklade metodiken är anpassade till sitt specifika ändamål inom organisationen. Exempel på detta är design- och inköpsavdelningar. Såväl en fullständig som en förenklad LCA är svår att kommunicera till personer som inte har deltagit i processen för användning av metoden eller verktyget. LCA-verktyg baserade på I/O metoden är praktiska eftersom de kan använda allmänt tillgängliga statistiska data. Den största svagheten är att de inte är lika intuitivt begripliga som LCA. LCA är lätt att förstå för vem som helst, även om det är ett komplicerat arbete att utföra en fullständig LCA. Nationell statistik och I/O-analys är komplexa och kan vara svåra att kommunicera.

Följaktligen, kan förenklade metoder och verktyg som LCA användas om förenklingen anpassats till situationen. Detta gäller såväl för SME som för stora företag, stater eller i internationella samarbeten. SME bör söka metoder och verktyg som är lätta att använda, tolka och delge och dela kostnaderna med t.ex. andra SME eller större företag. Offentligt finansierade initiativ och större företag bör söka strukturerade sätt att dela data och information, t.ex. genom att söka en harmonisering av miljöprestandaindikatorer.

S5 Data, tillgång och informationssystem

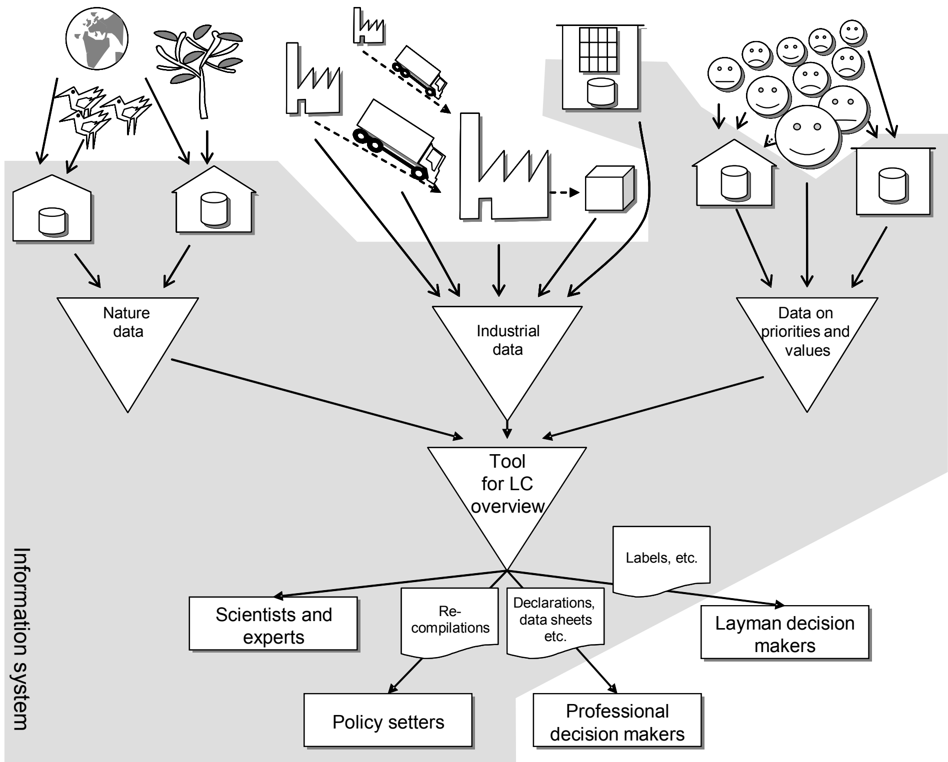
Figur S.2 visar att underlagsdata om aktuell status måste kommuniceras som miljöinformation till beslutsfattare och regelbundet uppdateras. Vissa metoder och verktyg uppdaterar den aktuella statusen väldigt sällan, t.ex. uppdateras LCI databaser och LC metoder för bedömning av miljöpåverkan ofta inte alls eller endast vart 5 till 10 år. Vanliga EMS-system uppdaterar den aktuella statusen minst en gång om året i den årliga miljörapporten. Oavsett hur ofta uppdatering sker, kan inte metoder och verktyg för bedömning av produkters miljöpåverkan ur ett livscykelperspektiv förenklas längre än till nödvändiga underlagsdata.

Miljöunderlagsdata är dyra och stora mängder krävs för en mängd material, utsläpp, produkter, produktionsställen, geografiska platser och olika miljöförhållanden. Det finns stora ekonomiska fördelar med att samordna insamlingen av miljöunderlagsdata och dela datakällor. Således är upprättande av gemensamma underlagsdata för miljöbedömning av produkters livscykler, en viktig ekonomisk strategi för hållbar utveckling i allmänhet och för varje lokalt miljöledningssystem vid produktionsanläggningar, liksom för kommuner, samhällen, företag, stater och internationell samverkan.

Denna rapport beskriver hur ett gemensamt format för underlagsdata för en mängd olika metoder och verktyg kan struktureras. Formatet medger delning av data för LCA, ERA, EMS, DfE etc. Rapporten listar också många tillgängliga källor till underlagsdata som kan användas för att tillhandahålla data till de olika metoderna och verktygen. För att tydligare visa varför befintliga datakällor inte tillgodoser alla behov, undersöks datatillgången på ett strukturerat sätt genom att föra in 6 dimensioner av tillgänglighet:

- *Förekomst*, dvs. huruvida just denna typ av data någonsin har strukturerats.
- *Täckning*, dvs. i vilken omfattning data täcker de exakta behoven.
- *Begriplighet*, dvs. huruvida data har dokumenterats så att de kan tolkas av en användare.
- *Underhåll*, dvs. huruvida det finns någon att kontakta för att få mer information om data.

- *Tillgång*, dvs. huruvida data faktiskt är tillgängliga för dataanvändaren med hänsyn till kostnad, sekretess etc.
- *Formatering*, dvs. huruvida data är uppdelade på olika dataområden i dokumentationen eller om de endast är tillgängliga som fri text i litteratur eller strukturerade i databaser.



Figur S.4 En förenklad översikt över uppläggningen av ett informationssystem för en bedömning av produkters miljöpåverkan på samhället ur ett livscykelperspektiv.

Figur S.4 beskriver tillgängliga datakällor, olika metoder, verktyg och användarkategorier som anges i sektion ”S3 Användare”. Denna organisation av underlagsdata, metoder, verktyg och användare utgör ett informationssystem. Informationssystemet är inte begränsat till geografiskt läge eller geografisk distribution. Avsikten är att datakällorna skall finnas på flera platser i världen, nära olika platser för utvinning av råvaror, transportvägar och produktionsanläggningar som är relaterade till en produkts livscykel. Läsaren bör beakta att uppdateringen inte sker så ofta och att informationen skall hanteras därefter.

Organisationen av datakällor och andra resurser i ett informationssystem beskrivs utförligt i rapporten, för att framhålla de viktigaste punkterna för att göra data tillgängliga för miljöbedömning av produkters livscykler.

Samordning av data- och informationsbehov är viktig liksom ett gemensamt format och en gemensam övergripande struktur. Dessa frågor tas upp i rekommendationerna i nästa sektion.

S6 Rekommendationer

Som nämndes i sektion ”S3 Användare” utgör professionella och övriga beslutsfattare de viktigaste användarna av informationssystemet. Dessa användare har emellertid inte intresse av hela miljöansvarskonceptet och hållbar utveckling utan är inriktade på beslut. Ansvaret för att upprätta ett informationssystem skall vila på politiska och proaktiva förespråkare och intressenter. Följande rekommendationer vänder sig till dessa förespråkare och intressenter.

Fastställ ramar för information

Det finns flera sätt att göra miljöinformation tillgänglig, men för att göra praktiska förbättringar av tillgången är det viktigt att klart ange vem informationen är avsedd för och hur den skall användas och för vilket ändamål. Jämför med sektion ”S3 Användare”.

Upprätta och harmonisera indikatorer för produkters livscykler

I sektion ”S2 Miljöbedömning av produkters livscykler”, introducerades miljöindikatorer som beteckning för enkel miljöinformation. När indikatorerna betyder samma sak för olika personer kan de förstås, diskuteras och användas i jämförelser och förbättringar etc. Detta är ett skäl för att harmonisera indikatorerna.

Det andra skälet för att harmonisera indikatorerna är den enorma mängd underlagsdata som krävs för att framställa den komprimerade informationen i en miljöindikator för en produkts livscykel. Tillgången till data kan underlättas om samma underlagsdata efterfrågas av många användare för en mängd applikationer så att arbetet med datainsamlingen inte splittras utan en stadig efterfrågan på data byggs upp.

Exempel på pågående aktiviteter är:

- UNEP/SETAC Life Cycle Initiative[37] som syftar till att omvandla livscykeltänkandet till praktisk handling och förbättra stödverktygen genom bättre data och indikatorer.
- COST Action 530[38] där målet är att överbrygga klyftan mellan grundläggande LCA-forskning och industrins behov av fungerande riktlinjer och modeller.
- Eco Procurement board har ingått avtal inom järnvägssektorn.
- CASCADE[39] projektet där format för miljödata har integrerats i existerande standarder för lagring och utbyte av material- och produktdata[40,41] som används inom andra tekniska områden. Projektet tillhandahåller också en lösning för hur nomenklaturer kan bibehållas på olika organisationsnivåer.

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37 UNEP/SETAC Life Cycle Initiative, http://www.uneptie.org/pc/sustain/lcinitiative/home.htm
38 COST Action 530, www.empa.ch/cost530
39 CASCADE, http://192.107.71.126/cascade
40 International Organization of Standardization, ISO 15926 Integration of life-cycle data for process plants including oil and gas production facilities
41 International Organization of Standardization, ISO 10303-235 Materials information for product design and validation (under development)

Ge stöd rörande metoder och verktyg

ALLMÄNT

Det finns ett stort antal metoder och verktyg för att förenkla miljöbedömning av produkters livscykler men de flesta verktyg har stora brister i tillgången på data. Många av de efterfrågade metoderna och verktygen finns, men det är inte sannolikt att de tilltänkta användarna kommer att hitta rätt verktyg utan experthjälp. En bättre matchning av användarnas behov och existerande metoder och verktyg rekommenderas.

Det rekommenderas dessutom att metoderna och verktygen skall delges användare och beslutsfattare i form av meningsfyllda miljöindikatorer och att olika förenklingar görs för skilda användare beroende på vem personen är och personens uppgifter.

LIVSCYKELANALYS

Det bör framhållas att en fullständig LCA i enlighet med t.ex. ISO 14040-serien är en väsentlig förenkling, eftersom den både begränsar och strukturerar arbetet med att sammanställa en livscykelbedömning. Oavsett antalet processer som inventeras och antalet inventeringsparametrar, påverkade kategorier eller kategoriindikatorer, kommer den ändå bara att ge en förenklad miljöbedömning av produkters livscykler.

Eftersom det finns många sätt att förenkla LCA rekommenderas att meningen med en förenklad livscykelanalys eller en förenklad miljöbedömning av produkters livscykler diskuteras på ett mer strukturerat sätt. Många förenklingar bör göras i fråga om insamling av data, detaljnivå, delgivning av resultat, användning av resultat eller verktyg för att göra komplexa LCAs. ”Förenklad LCA” är därför ett alltför vagt begrepp.

Det rekommenderas därför att användningen av harmoniserade indikatorer för miljöbedömning av produkters livscykler separeras från diskussionerna om metoder och verktyg för LCA.

Öka tillgången till data och information

Fyra aspekter skall beaktas vid upprättandet av gemensamma underlagsdata för miljöbedömning av produkters livscykler:

1. Fokusering på vilka användare och applikationer som data skall vara tillgängliga för. Inga generella lösningar finns.
2. Identifiering av vilka underlagsdata som behövs för att få fram den information de tilltänkta användarna och applikationerna kräver.
3. Strukturering av identifierade underlagsdata i ett allmänt format så att alla olika metoder och verktyg kan dela samma källor till underlagsdata.
4. En strategisk uppbyggnad av alla nödvändiga underlagsdata baserat på väl definierade miljöindikatorer för produkters livscykler.

Långsiktiga strategiska beslut bör fattas för att lösa tillgången till data för ett antal miljöindikatorer för produkters livscykler som är signifikanta för den globala, regionala och lokala miljön över hela världen samt för hållbarheten för kommande generationer. Sådana långsiktiga miljöindikatorer skall bestämmas och fastställas på olika strategiska nivåer, som t.ex. av FN, Världsbanken, USA, EU och andra regionala unioner av länder och stater, på nationell nivå, på industrisektornivå och inom offentlig upphandling och konsumtion. Indikatorerna skall sättas upp som långsiktiga mål för att driva handlingsplaner mot förbättrad datatillgång. Samverkan skall inledas och expertis ställas till förfogande för att stödja samordnade definitioner av indikatorer så att källor för underlagsdata och expertis tjänar så många syften och applikationer som möjligt.

De flesta källor för miljömässiga underlagsdata har upprättats för specifika ändamål med litet eller inget informationssystemssamband men är inte kompatibla tekniskt, konceptuellt och semantiskt. Därför rekommenderas stöd av internationellt standardiseringsarbete så att koncept, termer, gemensamma dataformat och nomenklatur kan utformas för att integrera data och information i olika system.

Utformning av informationssystem

Internationell, regional och nationell samverkan bör upprättas för att organisera ett informationssystem, genom praktiskt arbete såsom samordning av kompetens, stöd av harmonisering och standarder. Dessutom finns rekommendationer att detta arbete skall bygga på en långsiktig strategi och att kompetenskapacitet byggs upp genom t.ex. kunskapscentrer, datagenererare och hanterare. Sådan specialkompetens skall ges i uppdrag att stödja och samarbeta med företag, konsulter och mjukvaruförsäljare för att bygga upp en internationell, sektoroberoende, tvärvetenskaplig samverkan och genom en kombination av affärsmodeller och ansvar, arbeta fokuserat för att tillhandahålla miljöinformation till beslutsfattare under produktens livscykel.

En tydlig vision och fasta riktlinjer från statliga, industri- och icke-statliga ledare behövs för att upprätta detta informationssystem. Förespråkare och intressenter för miljöinformation rekommenderas därför starkt att själva åta sig denna uppgift med gemensamt ansvar för ett övergripande miljöinformationssystem.

S7 Första åtgärden

Inledning

I denna sektion framlägger författarna rekommendationer gällande vilka åtgärder som skall vidtas först för att förbättra tillgången till data för miljöbedömning av produkters livscykler genom fastställande av gemensamma underlagsdata. Dessa rekommendationer behöver inte tas i den ordning de framställs här. Åtgärderna bör vidtas gång på gång för att höja den strategiska nivån, öka kunskapen och den geografiska spridningen och nå ut till olika delar av samhället. Det förväntas också att kommitténs absoluta mandat kommer att utökas med tiden, med lämpligt anpassade mandat under de första upprepningarna. En naturlig utgångspunkt är begränsade pilotprojekt inom affärssektorer eller på nationell eller regional nivå.

Steg 1, riktlinjer och kompetens

Det första steget innebär att tillsätta politiska beslutsfattare, en ansvarig kommitté och upprätta en kompetensbas.

SAMARBETSKOMMITTÉ

Sätt samman en kommitté för samarbete (eller ett nätverk eller en organisation) av förespråkare och intressenter som bör utveckla rationella informationssystem. De bör vara villiga att ta hand om och skapa visioner och strategier. Kommittén bör upprätta feedback av information från både professionella och övriga beslutsfattare.

En viktig roll för kommittén bör vara att prioritera mellan uppgifter, bibehålla strategin och upprätta en säker långsiktig finansiering genom kontakter med finansinstitut och banker samt upprätta, driva och underhålla nödvändiga standarder.

Kommitténs strategiska arbete bör bestå i att upprätta och vidmakthålla internationell samverkan mellan EPAs, ledningar i multinationella företag och med den akademiska eliten inom berörda områden. Taktiken bör vara att driva program mellan organisationer, praktiska och väl definierade problemlösnings-/gap-överbryggande projekt, t.ex. definiera en specifik indikator, exportera en specifik databas till gemensamma format och starta en databas med specifika underlagsdata. Kommittén bör även separera forskning från implementering genom att överlämna ansvaret för implementering till ekonomiskt hållbara och sunda verksamheter. Forskningsfrågor bör snabbt skiljas ut och framläggas till en akademisk referensgrupp på strategisk nivå. Finansiering av forskning inom detta område bör baseras på problemlösning.

Det finns likheter mellan t.ex. UNEP/SETAC LC Initiative och samarbetskommittén, men skillnaden är att denna kommitté:

- Fokuserar på enkel information för miljöbedömning av produkters livscykler för slutanvändare, oavsett med LCA-metoden eller ej.
- Bedömer om enkel information skall ges till slutanvändare i första hand och metoder och verktyg i andra hand, medan UNEP/SETAC LC Initiative har framtagits av metodutvecklarna.
- Framhåller att underlagsdata är basen för all annan information. Insamling och tillgång till underlagsdata ingår inte i UNEP/SETAC LC Initiative, endast tätt komprimerade LCA-data och databaser.

Arbete bör i första hand bedrivas inom ramen för EU:s Joint Research Center och ISO där liknande samordnade aktiviteter pågår.

KUNSKAPSCENTRER

Upprätta kunskapscentrer kring redan existerande kompetensenheter, utvalda på kriterier som erfarenhet, praktiskt värde av den specifika kompetensen, tillväxtpotential i fråga om strategiska behov etc. Internationellt samarbete och kompetensdelning mellan olika kunskapscentrer skall främjas för att ytterligare driva på harmoniseringsprocesser samt delning av kompetens och erfarenhet.

Steg 2, ramar och format

Samarbetskommittén bör definiera ramar för vilka användare de skall rikta sig till, vilka applikationer som skall bedömas och vilka indikatorer som skall användas för att beskriva miljöbedömning av produkters livscykler. På basis av dessa beslut kan ett gemensamt dataformat utvecklas för utbyte av data mellan olika datakällor, metoder och verktyg. Formatet kan utvecklas av särskilda experter vid kunskaps-centrer och tillsammans med verktygsutvecklare och de som underhåller datakällorna.

- Dataformatet skall passa alla underlagsdata som de tilltänkta användarna behöver.
- Vara baserat på en allmän nivå av underlagsdata.
- Medge relevant dokumentation.
- Vara icke redundant, dvs. ekonomiskt och rationellt.

Steg 3, infrastruktur och informationssystem

På basis av de valda och definierade indikatorerna utveckla användningen av det gemensamma formatet för att upprätta infrastrukturer och kommunikationskanaler för att dela data från källor till (först) professionella beslutsfattare och (därefter) övriga beslutsfattare. Detta innefattar praktisk samverkan mellan de som underhåller datakällorna, verktygsutvecklarna och it-experter.

Underhållare av datakällor bör stödjas vid behov för att tillhandahålla nödvändiga underlagsdata och upprätta publiceringsrutiner. Kompetenser för komprimering av underlagsdata till olika lager av mindre komplicerade data är också värdefulla, såsom riskanalytiker, miljövårdare och LCA-konsulter etc. Dessutom, är det nödvändigt att finna sätt att motivera andra informations-, metod- och verktygsutvecklare och experter inom relevanta områden, såsom politiska beslutsfattare, datapublicerare, mjukvaruutvecklare för att utveckla t.ex. PCRs, produktdesignkriterier och miljöupphandlingskriterier etc.

Detta bör leda till en fullständig kartläggning av informationssystemet, liknande figur S.4 för en viss grupp av användare, en specifik applikation och en specifik indikator. Varje komponent eller modul bör vara bekräftad och varje gap identifierat.

Steg 4, generera nya data och bevara kunskap

Kommittén bör identifiera internationella industrier, länder och finansiärer som är beredda att fullgöra och upprätthålla fullständiga bedömningar ur ett livscykelperspektiv i avsikt att förvärva och upprätta bättre datatillgång och kunskaper.

Steg 5 och vidare

Kommittén bör kontinuerligt arbeta för nödvändiga förbättringar och inrikta sig på att avlägsna några prioriterade hinder i taget. Den bör sätta upp snäva tidsramar för slutförande av projekt och fortlöpande bedöma om praktiska framsteg gjorts. Flexibilitet, pragmatism och praktiska resultat bör ligga till grund för att kommittén skall lyckas, liksom samarbete, samförstånd och samordning.

Upprättandet av gemensamma underlagsdata för miljöbedömning av produkters livscykler, är således praktiskt arbete som kan utföras med en strategisk vilja och kontinuerliga förbättringar.

Strategisk vägledning för utveckling av informationssystem på olika nivåer kommer också att behövas, såsom avancerade tekniska och tvärvetenskapliga expertnivåer, såväl som strategisk samordning och visionär vägledning.
Sådan kompetens kräver en specifik tvärvetenskaplig och mellanorganisatorisk struktur i skärningspunkten mellan miljövård och datahantering. En del av den erforderliga kompetensen kanske måste byggas upp och etableras men mycket kompetens finns redan idag i form av industri- och akademiska forskningsenheter, utbildningsinstitutioner och som affärskonsulter och mjukvaru- eller databasleverantörer. Exempel på detta är databashanterare vid Europeiska kemikaliebyrån (ECB), de nationella Naturvårdsverken (EPAs), specialiserade forskargrupper som arbetar med miljöinformatik vilka möts på konferenser som International Society for Environmental Information Sciences[42] och Informatics for Environmental Protection[43]. Ny kompetens har också byggts upp runt upprättandet av t.ex. LCA-databaser och den japanska LCA-databasuppbyggnaden vid JEMAI[44], den schweiziska databasvärden EcoInvent[45] samt den svenska tvärvetenskapliga forskargruppen Industriell Miljöinformatik, IMI, vid Chalmers Tekniska Högskola är exempel på detta. Kompetensgrupper kan utses till kunskapscentrer för global uppbyggnad av ett informationssystem för miljöbedömning av produkters livscykler. Sådana kunskapscentrer skall ha till uppgift att utveckla, underhålla och sprida data, information och kunskap om:

- Miljödata och information, nomenklaturer och statistik.
- Protokoll och överenskommelser rörande miljödatabaser, datakommunikation, datadelning och datalager.
- Metoder och verktyg, modularisering och gränssnitt mellan informationssystem för miljöutvärdering.

Vissa praktiska erfarenheter från sådana kunskapscentrer är en långsiktig tillgång, tillgänglighet och uppbyggnad av kunskap om hur ett informationssystem för miljöbedömning av produkters livscykler byggs upp och hur miljöinformation och data används för bedömning av produkters miljöpåverkan ur ett livscykelperspektiv. Kunskapscentrer bör också vara experter t.ex. på att hitta tillgängliga data och bistå med upprättande av nya källor till underlagsdata.

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42 International Society for Environmental Information Sciences, http://www.iseis.org
43 Informatics for Environmental Protection, http://www.enviroinfo2005.org
44 JEMAI, http://www.jemai.or.jp/english/index.cfm
45 EcoInvent, http://www.ecoinvent.ch

1 Introduction

1.1 Background

The commission for this report is to give a state-of-the-art presentation of how information about the environmental life cycle performance of products can be made available to relevant stakeholders, including producers, procurers and citizens. We have also been instructed to propose improvements or solutions to establish an information system of this kind. The aim is to describe how the same primary data can be used in different applications and by different users to achieve synergies and cost-effectiveness. The report should not be limited to Sweden or Europe or to any specific sector, but should take account of the fact that product life cycle information is a global issue.

The authors were instructed to specifically refer to the contents of a number of reports commissioned during earlier phases of Swedish EPA efforts in this field. The authors have made extensive further literature studies, and references are added as footnotes in the text and as a reference list at the end of the report.

The report describes how any stakeholder anywhere can find and assess environmental performance information about products throughout product life cycles. The report takes account of many parallel definitions of environmental product life cycle performance, such as energy demand, waste generation, content of toxic substance, recyclability, etc. Owing to the breadth of the product life cycle concept, the report devotes great attention to the way information is treated by the various life cycle assessment (LCA) methods, but is not limited to LCA. Information needed for risk assessment (RA), material content inventory, design for environment etc. are also covered and examined in detail. An attempt has been made to describe information needed to assess environmental life cycle performance of any type of product, whatever the scope or level of detail chosen for the assessment.

The report focuses on material the authors consider necessary to supplement that which has already been achieved by the referenced material. Four new contributions in this report are to:

- clarify the function and purpose of the information system, such as that environmental information is always for decision making;
- clarify user requirements, by distinguishing four user categories and some perspectives for environmental overview of product life cycles;
- distinguish between information input and output for methods and tools by specifying data input needs for relevant methods and tools, and to show how primary data may be structured;
- define the scope and content of environmental data and information by proposing that it is data and information used specifically for environmental decisions or assessments.

1.2 Overviewing product life cycles

1.2.1 Overviewing life cycles using environmental information

Figure 1 shows a product life cycle and how it impacts the natural environment. The diagram focuses on the manufacturing process, and the life cycle can be followed upstream through transport, refinement and extraction processes. It can also be followed downstream through other transport, use processes and waste treatment. For any product the focal point may be shifted to other processes or transport over its life cycle.

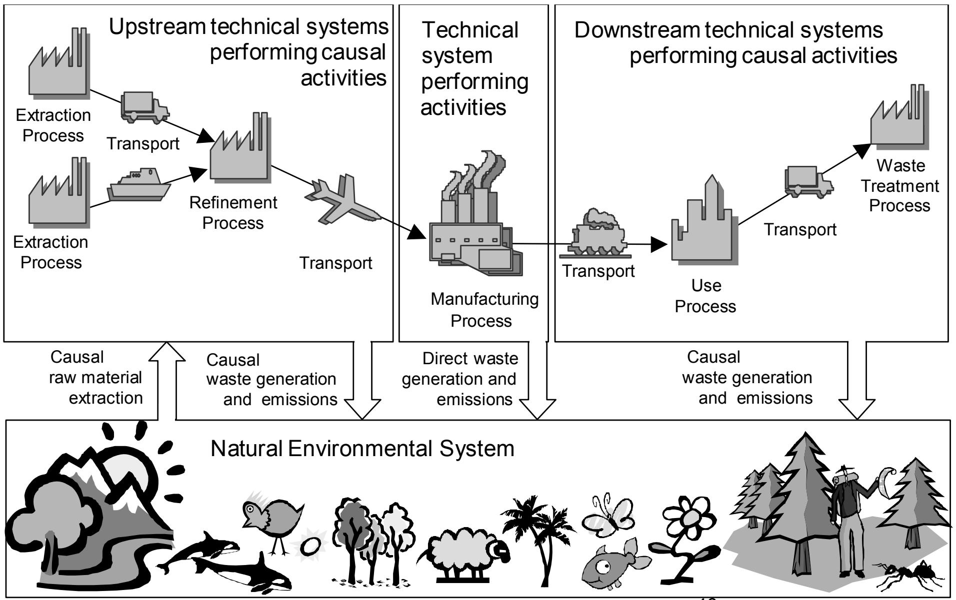

Figure 1. A schematic product life cycle and its environmental impact[46]. Used with permission. Copyright Raul Carlson and Ann-Christin Pålsson, CPM, Chalmers University of Technology, 1998.

To emphasise the significance of information and data in the context of environmental product life cycles it must be stressed that a life cycle as depicted in Figure 1 bears little resemblance to a real-life product life cycle; the distinct processes and transport, the surrounding system boundaries, the flows between process and into and out of the ecosystem, and the natural environment with separate mountains, water, animals and plants are all gross simplifications of everything involved in an actual product life cycle. In reality everything is connected to everything else, with mutual dependencies. The boundaries in the diagram are not there, and the distinct items and arrows cannot be found. For example, manufacturing a plastic housing for a vacuum cleaner requires not only the raw plastic and energy to melt and cast it, but also energy for transport systems at the factory, spare parts for the machines, the building of the production facility, cleaning chemicals for the moulds, paper, computers and printers, cables, light bulbs, showers and soap in the changing

[46] Carlson R, Pålsson A-C (1998), *Maintaining Data Quality within Industrial Environmental Information Systems*; 12th International Symposium 'Computer Science for Environmental Protection' Bremen 1998; Band 1/Volume 1 p. 252-265.

rooms for the workers, etc. All the large and small articles needed to make the housings also have life cycles of their own. The production facility generates waste and emissions, not only from the melting of plastics, but from the cold plastics, and from grease, cleansing chemicals, towels, soap, printed paper, boxes etc. Nature is affected via even more complicated dependencies, from immediate impacts such as disturbance of ecosystems, release of toxic substances and depletion of natural resources, to anthropogenic impacts such as lower agricultural yields, poorer quality of life or reduced life expectancy. In real life all the life cycles needed to produce a plastic housing are interrelated with so many technical and natural processes that it is impossible to fully describe them graphically or in words. Nobody will ever have the resources to acquire all this information and no-one can make sense of so much data. Hence, environmental overviews of product life cycles are based on selections of relevant information, i.e. simplifications. Different simplifications are needed for different purposes and by different people, depending on the aspects of a product's environmental performance in which they are interested.

To gain an initial understanding of how people actually view their need for environmental information and data, we asked a handful of people with different roles using environmental data in various contexts for various purposes what they needed. These ‘interviewees’ were selected to represent a wide range of subjects, from laymen in the field of environmental sciences, to industrial environmental experts, environmental policy makers and highly skilled and experienced environmental scientists. Extracts from their responses are given below, selected to illustrate their differing needs.

- 'The everyday consumer “wants to know what is true" in the immense information flow from which contradictory conclusions may often be drawn. In a specific situation, e.g. a major investment, the consumer is interested in studying facts to obtain support for his decision so that the right choice can be made.'
  Christer Carlsson, Gothenburg
- 'To improve its environmental performance, the company needs information about its production processes, about emissions and energy and raw material consumption. The expression “what is measured is improved" is true.'
  Ellen Riise, Environmental controlling and assessment, SCA Hygiene Products
- 'The policy maker needs information on the consequences of environmental regulations and agreements. The environmental gain must be compared with the financial impact on companies and society. Reporting requirements must be very explicit so as to coordinate the flow of environmental information. The same facts are generally requested by different actors but in different formats.'
  Inger Strömblad, Confederation of Swedish Enterprise
- 'The policy maker needs information on the state of the environment, e.g. scientific research findings, species survey results, official emission statistics. There is so much information that the difficult part is to assure quality and separate out the useful parts. A lot of the existing information is not compiled into useful results. And many information sources are not accessible at a reasonable cost.'
  Anders Friström, Swedish Society for Nature Conservation

- 'For the environmental scientist the question "What environmental information does an environmental scientist need?" is as broad as the question "What is your opinion about life?" Examples of environmental information used in scientific environmental research are physical and chemical properties such as thermal conductivity, dissolving capacity, diffusion rates etc.
  Associate Professor Olle Ramnäs, Chemical Environmental Science, Chalmers University of Technology

These answers were obtained and are included here to illustrate some important fundamentals of this report, i.e. that:

- Different users of environmental information need different types of information.
- All users call for selected information.
- No user wants all information about everything.
- Decision makers want credible facts that are relevant to their decisions.
- Policy makers want many items of significant information of high quality to use as a basis for policies.
- Environmental scientists need different information depending on the scientific topic but have a specific need for facts with good scientific transparency.

There are many examples where these types of environmental information needs are expressed for reporting systems, management systems, methods and tools, such as key environmental aspects[47], environmental performance indicators[48], environmental condition indicators[49], category indicators[50], data categories[51], reporting variables[52, 53, 54], etc. Various environmental indicators are needed when evaluating the environmental performance of activities, processes, hardware, and services[55], work being performed by various organisations, such as ISO, OECD, EU, GRI, WEF and WBCSD to define environmental indicators[56].

Usually, it is not clearly stated that singular indicators (categories, variables, etc.) should be selected so that together, they represent a greater larger whole, such as the overall environmental performance of an entire production plant or the

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47 International Organisation for Standardisation (1997), *ISO 14001: Environmental management systems - Specifications with guidance for use.*

48 European Commission (2003), *2003/532/EC, Commission recommendation of 10 July 2003 on guidance for the implementation of Regulation (EC) No 761/2001.*

49 International Organisation for Standardisation (1999), *ISO 14031: Environmental management - Environmental performance evaluation – Guidelines.*

50 International Organisation for Standardisation (2000), *ISO 14042: Environmental management - Life cycle assessment – Life cycle impact assessment.*

51 International Organisation for Standardisation (1997), *ISO 14040: Environmental management - Life cycle assessment - Principles and framework.*

52 Global Reporting Initiative (2002), *Sustainability Reporting Guidelines*, http://www.globalreporting.org/guidelines/2002/gri_2002_guidelines.pdf.

53 Naturvårdsverket (2002), *Planering och utformning av miljöövervakningsprogram*, viewed at http://www.naturvardsverket.se/dokument/mo/hbmo/del1/plan/upplagg4.pdf.

54 World Economic Forum (2005), *2005 Environmental Sustainability Index – Benchmarking National Environmental Stewardship.*

55 Carlson R (2002), *Environmental Performance Indicators*, Published in INSIGHT, Vol 5 Issue 2 July 2002 p. 22-23, The International Council on Systems Engineering (INCOSE).

56 General environmental indicator links can be found at: http://www.pepps.fsu.edu/EI_Gen.html.

overall environmental performance of a product life cycle. But this is in fact the aim: to select a few pieces of information, i.e. indicators, that, when taken together, represent the whole.

For example, the mass of a vehicle may be used to represent its energy requirement throughout its life cycle, but not alone, since its actual use and the power of its propulsion and energy systems must also be represented by indicators. Hence, the environmental life cycle aspects of a specific type of vehicle may be expressed in terms of three indicators (mass, power, fuel). This set of indicators is simpler to describe and easier to understand than a full specification of the entire vehicle, or even the physical vehicle itself. These three indicators might not suffice for the same type of vehicle in another situation. Someone might require information on emissions, noise or about expected lifetime. And for full life cycle design it may also be important to know about the presence of renewable or recyclable material, toxic substances etc. (mass, power, fuel, noise, expected lifetime, presence of renewable materials, presence of recyclable materials, presence of toxic substances, etc.)

Thus, an unlimited number of indicators may be thought of to describe possible aspects of the environmental life cycle performance of vacuum cleaner housing or a vehicle. It is difficult and time-consuming to identify these indicators so that they are significant, relevant and understandable, and so that the cost of acquiring the primary data needed and collating the resulting information is acceptable[57, 58]. But the alternative to using indicators is that any environmental information, good or bad, will not provide a contribution to the environmental overview of a product life cycle, since its significance, relevance and meaning are not examined and understood.

This report is based on the premise that environmental information without a purpose and scope defined in terms of an indicator or a significant aspect, for example, is not informative. If primary environmental data and information is effectively and efficiently to inform the public, policy makers, decision makers or experts, then environmental product life cycle indicators must first be defined. This report starts by identifying those who define these indicators, and goes on to examine the information and primary data they need.

1.2.2 Supplying users with information from different data sources

The term *primary data* in this report refers to the lowest level of aggregated data needed to produce a desired piece of information. This section describes how primary data are needed to produce simple information for users, focusing on the need to organise data sources, information channels and data handling. To exemplify this, the two simple indicators *presence of renewable materials* and *presence of recyclable materials* will be examined in detail (see section 1.2.1).

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[57] Flemström K (2003), *Environmental Performance Indicator (EPI), Methodology in REPID*, Chalmers University of Technology, Sweden.

[58] Carlson, Tivander, Erixon et al. (2004), *Conceptual model report,* OMNIITOX project report 2004, www.omniitox.net.

- *Presence of renewable materials*
  Basically, a material is renewable if it can be harvested and grown again within a time shorter than a few generations, i.e. around 150 years. Naturally, these facts cannot be acquired from the material itself, since a piece of wood, for example, does not reveal whether the tree it came from was felled in a forest being depleted faster than it can be regenerated, or whether new seedlings were planted in its place. Data distinguishing whether a material is renewable or not must be based on the history of the data and on some ecological facts about the origin of the material. Information must be transferred from the origin of the material to the final information user, as a document attached to the material, as a general document about the operators throughout the supply chain, or as a reference to a library that the user can access.
- *Presence of recyclable materials*
  A material is recyclable if it can be turned into the same or a new valuable raw material after it has been part of a used product. In theory any material is recyclable, since it is theoretically possible to separate all the atoms in a used vehicle, for example, and to recycle them into any material by artificial or natural processes. Cost is the limiting factor. Recycling naturally occurs when it costs less to use recycled materials than virgin ones. The cost factors are the cost of collecting the discarded product, the scrapping process and refinement to produce a useful raw material. To assess recyclability is to compare the price of virgin materials with the cost of recycling. But environmental concerns and a constantly growing demand for industrial materials have made recycling a technology as well as a rapidly growing industry. Put simply; future recycling costs are difficult to calculate. Data on whether a material is recyclable or not are based on estimated costs of virgin materials, information about how the product is discarded and models of waste management systems, about how to disassemble the product and scrapping technologies, and about technologies and energy requirements for refinement. These complex primary data are collated by experts into simple information as to whether a material is recyclable. The primary data is first communicated to the expert, and the results are transferred to all users throughout the supply chain. If the material is used in new components and products throughout the supply chain, its recyclability will again be altered, and this change must also be communicated to end users of the information.

These two examples show that it is difficult and costly to produce simple information for environmental overview of product life cycles. When product life cycle studies are made merely to acquire new knowledge, access to data sources and necessary expertise may be dealt with ad hoc: consultants and experts at academic institutions may be hired on a project basis to collect primary data, to perform assessments, and to make judgments and interpretations. But this will not do when putting learning into practice for continuous improvement and sustainable development throughout our industrial society.

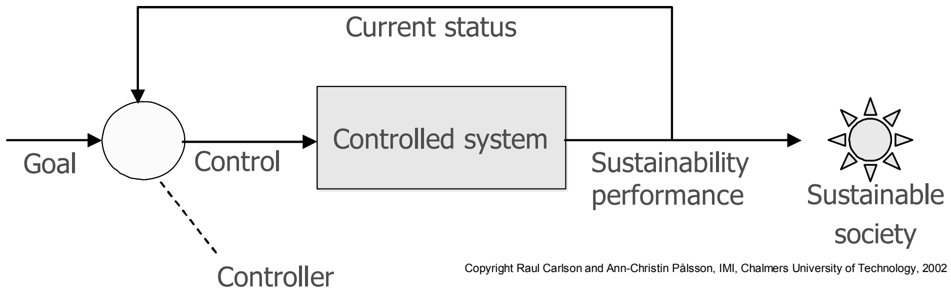

Figure 2. A model showing how decision makers/controllers use environmental information to work towards a sustainable society[59].

Figure 2 is a model showing the strategic role of environmental information for continuous improvement and sustainable development. The model considers any decision-maker to be a controller of sustainable development. The controller may be a consumer or a professional procurer choosing between products, a product designer choosing materials or functions, or any business or political decision-maker deciding strategies or investments. The environmental performance information about both *current status* and the intended *goal* are given to the controller. The controlled system and the goal are constantly changing, not only because of the decisions the controller takes, but also due to factors such as consumer behaviour, production technologies, business competition, changes in the natural environment, people's values and priorities, etc. When new knowledge is acquired, the definition and meaning of sustainable development also changes. Hence, the controller navigates a moving system towards a moving target. Goal and status informatinon must be upadted frequently to achieve constant improvements.

The fact that data needs to be updated frequently combined with the difficulty and cost of producing simple environmental information even once suggests there is an urgent need for a systematic strategy for handling primary data acquisition and managing data sources. There is also a need for strategic organisation of the necessary expertise to produce both the simple information for end users and all intermediate data aggregations. In this report organisation of data, information, interpretation and data handling in this way is called an *information system*. The term "information system" is thus used in the wide sense of strategies to cooperate for continuous primary data and information supply, rather than the narrower sense of a database system, software architecture or data management organisation, for example. These "smaller" information systems are considered to be crucial components of the strategic information system described in this report.

[59] Carlson R (2004), *The Industrial Environmental Informatics Instrument*, IMI Report 2004:1.

1.3 State of the art

The environmental impact of products and services originates from all phases of the life cycle of products or services, from cradle to grave[60]. This report focuses on the information describing this environmental impact, and how data acquired on one occasion can be reused for many purposes.

There are many methods and tools that produce information on aspects of the environmental life cycle performance of products and services. The intended users of this information vary; often the person using the tool is not the person using the resulting information. For example, the typical LCA practitioner is an environmental expert at a company or a consultant and the information user is a product developer or a purchaser.

The tools can be classified in different ways. One is to classify them into "bottom-up" and "top-down" tools on the basis of their modelling approach. The bottom-up approach is based on modelling unit processes that can be aggregated into a description of the life cycle of the product or service. The unit processes may be raw material abstraction, transport, manufacture, use, disposal or any other phase of the life cycle. These processes are thus the cause of the environmental impact. Examples of bottom-up tools are LCA and RA. In the top-down approach, the environmental performance of the product is derived by allocation (usually economic) from all inputs and outputs caused by the total production of a product category. With this approach it is instead the product that bears the environmental impact, instead of the associated processes. Examples of top-down tools are I/O analysis and material flow analysis[61]. The choice of tool and system boundaries depends on the intended purpose of the information produced, which may be comparison between solutions, review of the company's environmental performance or analysis of future scenarios[62].

The data sources also differ in these two approaches: the top-down tools are usually designed to use statistical or average data for product categories, while bottom-up tools are designed to use specific data describing or modelling physical objects or processes. Current data sources cover mostly the manufacturing of products, while data about use and disposal of products are rare. Some examples of data sources containing data needed for environmental assessments of products are environmental reports, product data management systems, and data sheets and declarations[63]. Statistical data are collected by the national statistical authorities in most countries[64]. For life cycle studies there are databases containing both inventory data and characterisation data[65]. Actual data availability depends on many

[60] Naturvårdsverket (2002), *Kunskap om produkters miljöpåverkan: tillgång, behov och uppbyggnad av livscykeldata*, Swedish EPA Report 5229, page 42.
[61] Naturvårdsverket (2002), *Kunskap om produkters miljöpåverkan: tillgång, behov och uppbyggnad av livscykeldata*, Swedish EPA Report 5229, chapter 4.
[62] Naturvårdsverket (2002), *Kunskap om produkters miljöpåverkan: vad ger dagens statistik?*, Swedish EPA Report 5231, page 17.
[63] Naturvårdsverket (2002), *Kunskap om produkters miljöpåverkan: tillgång, behov och uppbyggnad av livscykeldata*, Swedish EPA Report 5229, chapter 6.
[64] Naturvårdsverket (2002), *Kunskap om produkters miljöpåverkan: vad ger dagens statistik?*, Swedish EPA Report 5231, page 43.
[65] Naturvårdsverket (2003), *Att mäta produkters miljöbelastning*, Swedish EPA Report 5269, page 26.

parameters, such as the format of the data. Examples of data formats for LCA data sharing are the EcoSPOLD format and the ISO/TS 14048 format. Formats intended for communication between people include eco-labels and EPD product declarations[66]. Appendix 2 to this report contains a thorough exposition of available data sources and formats.

In spite of the different data sources and formats available, the actual status of environmental information is a lack of data, particularly on the use phase of products and on environmental impacts caused by toxicity, for example[67]. There is a need for improved management of data for environmental overview of product life cycles, and there are currently numerous actors proposing various solutions and designs for information systems.

1.3.1 Sources used in the report

Previous work by the Swedish EPA on environmental product information has been considered in this report. The authors were instructed to refer specifically to a number of reports commissioned by the Swedish EPA. The IVL report commissioned by the Swedish EPA suggests that efforts to acquire life cycle data must be pursued as a combined initiative by regulatory and industry organisations, in which goals should be set by government bodies, and information on processes and products is provided by industry[68]. The report by Statistics Sweden examined the potential of national statistics to meet the need for environmental product information[69]. The report by CPM (Centre for Environmental Assessment of Product and Material Systems) covers the centre's experience of tools, methods and providing information on the environmental impact of products[70].

Other work has been conducted at the Swedish Chemicals Inspectorate, which has scrutinised the information available on chemical substances [71]. The Swedish EPA also asked IMI to produce a report on the scope for coordinating work on life cycle assessment and risk assessment[72].

1.3.2 IMI experience

The Chalmers research group Industrial Environmental Informatics (IMI) has its origins in LCA data modelling based on conceptual modelling techniques, which produced the LCA data format SPINE[73], and the establishment of a Swedish national LCA database SPINE@CPM[74]. Between 1996 and 1998 the Swedish

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[66] Naturvårdsverket (2003), *Att mäta produkters miljöbelastning*, Swedish EPA Report 5269, page 23.
[67] Naturvårdsverket (2003), *Att mäta produkters miljöbelastning*, Swedish EPA Report 5269, chapter 4.
[68] Naturvårdsverket (2002), *Kunskap om produkters miljöpåverkan: tillgång, behov och uppbyggnad av livscykeldata*, Swedish EPA Report 5229.
[69] Naturvårdsverket (2002), *Kunskap om produkters miljöpåverkan - vad ger dagens statistik?*, Swedish EPA Report 5231.
[70] Naturvårdsverket (2003), *Att mäta produkters miljöbelastning*, Swedish EPA Report 5269.
[71] KemI (2004), *Information om varors innehåll av farliga kemiska ämnen.*
[72] Naturvårdsverket (2004), *Relationships between Life Cycle Assessment and Risk Assessment – Potentials and Obstacles*, Swedish EPA Report 5379.
[73] Carlson R, Löfgren G, Steen B (1995), *SPINE – A Relational Database Structure for Life Cycle Assessment*, Report B1227, Swedish Environmental Research Institute, Gothenburg.
[74] Carlson R, Pålsson A-C (1998), *Establishment of CPM's LCA Database*, CPM Report 1998:3, Chalmers University of Technology, Sweden.

national competence centre CPM financed the establishment of SPINE@CPM, which was based on the SPINE format and on data quality principles[75] based on industrial total quality management. Practical experience was gained of the difficulties of acquiring industrial LCA, environmental information management and data availability in general. Data acquisition and maintenance methods were developed in the quest to increase the availability of data for LCA studies[76,77]. These methods were tested in a project involving both CPM and representatives from the Swedish pulp and paper industry on collecting and managing environmental data at production sites[78].

IMI's experience of environmental information management has also been applied and developed in European joint research projects. The RAVEL project[79] ran between 1998 and 2001 and joined partners representing the entire rail sector (operators, manufacturers and sub-contractors) and Design for Environment (DfE) consultants. DfE was implemented in the product development process to improve the eco-efficiency of rail vehicles. After the successful RAVEL project the EU also helped to fund implementation of the results in the rail industry, as the REPID project[80] which ran between 2002 and 2004. REPID aimed at establishing a REPID database containing all data needed to perform an eco-efficiency calculation of a rail vehicle, the REPID material list, which is a standard list of all materials handled in the rail industry, and the REPID tool, which is a software tool to assess the environmental performance of a rail vehicle[81]. IMI's role in REPID was to serve as a source of expertise – a conduit communicating the RAVEL findings to the industry, and to develop databases, material lists and user manuals for RAVEL methods.

IMI also participated in the joint European project OMNIITOX between 2001 and 2004. The OMNIITOX project[82] developed characterisation models and characterisation factors for the effects of toxic substances on humans and nature for which there is a European scientific consensus[83]. IMI's role in that project was to establish the formal correctness of various environmental impact models, and to construct the OMNIITOX database and information system containing primary

75 Arvidsson P et al (1997), *Krav på datakvalitet CPM:s database 1997*, CPM Report 1997:1, Chalmers University of Technology, Sweden.

76 Carlson R, Pålsson A-C (1998), Maintaining Data Quality within Industrial Environmental Information Systems; 12th International Symposium 'Computer Science for Environmental Protection' Bremen 1998; Band 1/Volume 1 p. 252-265.

77 Carlson R, Pålsson A-C (2001), Industrial environmental information management for technical systems, Journal of Cleaner Production, 9 (5): 429-435, Elsevier Science Ltd.

78 SSVL and Chalmers (2002), *Methodology for handling forest industry environmental data – Method report;* the report can be found at: http://www.dantes.info/Strategies/EnviroSuppPHASETS/Doc/Method%20report%20%20Methodology%20for%20handling%20forest%20industry%20environmental%20information.pdf.

79 Dewulf W, Duflou J, Ander Å (2001), *Integrating Eco-Efficiency in Rail Vehicle Design*, Leuven University press.

80 Railway procurement network, http://www.railway-procurement.org/default.htm

81 Flemström K (2003), *Environmental Performance Indicator (EPI), Methodology in REPID*, Chalmers University of Technology, Sweden.

82 OMNIITOX (Operational Models aNd Information tools for Industrial applications of eco/TOXicological impact assessments), www.omniitox.net .

83 Carlson, Tivander, Erixon et al. (2004), *Conceptual model report,* OMNIITOX project report 2004, available at www.omniitox.net.

data on the physical, chemical and toxicological properties of substances[84]. IMI also produced the software tool to calculate characterisation factors from those primary data.

Knowledge and experience from the work on the SPINE format contributed to the establishment of the technical specification ISO/TS 14048 Environmental management – Life cycle assessment – data documentation format, finalised by ISO in 2001[85]. IMI has also taken part in the European thematic network CASCADE[86], aiming to adapt LCA data formats for industrial purposes, such as Computer Aided Manufacturing (CAD) and Product Data Management (PDM) standards. IMI is also participating in the Life programme demonstration project DANTES[87] with particular interest in demonstrating strategies for environmental information management and environmental databases and software.

This experience has enabled IMI to learn how to produce databases, how to establish data formats and how to make the results useful.

1.3.3 Powerful forces

The universal nature of environmental problems compels many actors to become involved, including authorities, trade associations, NGOs and consumers. These are powerful forces, which all have their views on the present and the desirable state of the environment[88]. These actors have various means of control they can use to achieve sustainability, such as legislation, regulations, environmental labels and declarations, standards, directives etc[89]. The actors also all have varying information needs. Environmental information must therefore be documented, formatted, stored and presented so that it will suit its intended use, and features such as focus, level of detail, communication format, interpretation, system boundaries, and aggregation level will vary[90]. The differing viewpoints and needs of actors are examined further in Chapter 2 of this report.

1.3.3.1 REGULATIONS

Agenda 21[91] was adopted by the United Nations Conference on Environment and Development on 14 June 1992 in Rio de Janeiro. Agenda 21 is the global community's commitment to sustainable and environmentally sound development in all

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84 Erixon et al. (2003), *Data Source Inventory Report*, OMNIITOX project report, available at www.omniitox.net.

85 Carlson R, Pålsson A-C (2001), *First examples of practical application of ISO/TS 14048 Data Documentation Format*, CPM Report 2001:8, Chalmers University of Technology, Sweden.

86 Weidema B P, Cappellaro F, Carlson R, Notten P, Pålsson A-C, Patyk A, Regalini E, Sacchetto F, Scalbi S (2003), *Procedural guideline for collection, treatment, and quality documentation of LCA data*, Document LC-TG-23-001 of the CASCADE project.

87 http://www.dantes.info/.

88 Naturvårdsverket (2002), *Kunskap om produkters miljöpåverkan: tillgång, behov och uppbyggnad av livscykeldata*, Swedish EPA Report 5229, Appendix 1.

89 Naturvårdsverket (2002), *Kunskap om produkters miljöpåverkan: vad ger dagens statistik?*, Swedish EPA Report 5231, page 16.

90 Naturvårdsverket (2002), *Kunskap om produkters miljöpåverkan: tillgång, behov och uppbyggnad av livscykeldata*, Swedish EPA Report 5229, page 29.

91 UN (1992), *Agenda 21*, available at http://www.un.org/esa/sustdev/documents/agenda21.

countries. The Rio Declaration on Environment and Development[92] was adopted at the same conference, as were principles for the sustainable management of forests[93]. The process had a follow-up in Johannesburg in 2002. Another UN document having a major strong global influence on environmental protection and policy is the Kyoto protocol[94].

Sustainable development is one of the goals of the European Union, and the principle was incorporated in the EC constitution by the Amsterdam Treaty in 1997[95]. The European Commission has produced several influential directives and other documents on the environment, dealing with various issues such as IPP[96], emissions trading[97], risk assessment[98], green purchasing[99] and environmental management[100].

Sustainability can also be broken down into more specific aims. The Swedish Parliament, for example, laid down 15 environmental quality objectives in 1999[101]. Other influential laws passed by the Swedish Parliament are the Producer Responsibility for Motor Vehicles Ordinance[102] and the Environmental Code[103]. Many industrial organisations also express environmental performance concerns and objectives in their environmental policies[104].

1.3.3.2 STANDARDS

The International Organisation for Standardisation has developed a number of standards for environmental management[105], communication of environmental performance of products[106], and data representation and exchange[107]. In addition, organisations such as the Global Reporting Initiative (GRI)[108] and World Business

[92] UN (1992), *Rio Declaration on Environment and Development*, available at http://www.un.org/esa/sustdev/documents/UNCED_Docs.htm.
[93] UN (1992), *Statement of principles for the Sustainable Management of Forests*, available at http://www.un.org/esa/sustdev/documents/UNCED_Docs.htm.
[94] UN (1997), *Kyoto protocol to the United Nations framework convention on climate change*
[95] European Union (1997), *The Amsterdam Treaty*.
[96] European Commission (2001), *Green Paper on Integrated Product Policy*.
[97] Commission Decision of 29/01/2004, *Establishing guidelines for the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council*, Brussels, 2004.
[98] ECB (European Chemical Bureau) (2003), *Technical Guidance Document in support of Commission Directive 93/67/EEC on Risk Assessment for new notified substances, Commission Regulation (EC) No 1488/94 on Risk Assessment for existing substances.*
[99] http://europa.eu.int/comm/environment/green_purchasing/cfm/fo/greenpurchasing.
[100] European Commission (2001), *Regulation (EC) No 761/2001 of the European parliament and of the council of 19 March 2001 allowing voluntary participation by organisations in a Community eco-management and audit scheme (EMAS)*.
[101] Sveriges Miljömål, http://www.miljomal.nu.
[102] Sveriges riksdag (1997), *The Producer Responsibility for Motor Vehicles Ordinance*, Svensk författningssamling (SFS) 1997:788.
[103] Swedish Environmental Code (Miljöbalken), viewed at http://www.ekolagen.se/29sveeng.htm.
[104] Naturvårdsverket (2003), *Att mäta produkters miljöbelastning*, Swedish EPA Report 5269.
[105] International Organisation for Standardisation (1997), *ISO 14001: Environmental management systems – Specifications with guidance for use.*
[106] International Organisation for Standardisation (2002), *ISO/TR 14025: Environmental labels and declarations - Type III environmental declarations.*
[107] International Organisation for Standardisation, *ISO 10303 Product Data Representation and Exchange* (multi-part standard).
[108] Global Reporting Initiative (2002), *Sustainability Reporting Guidelines*, http://www.globalreporting.org/guidelines/2002/gri_2002_guidelines.pdf.

Council for Sustainable Development (WBCSD)[109] have developed guidelines for reporting and choice of indicators of environmental performance.

1.3.3.3 ORGANISATIONS THAT ORGANISE INFORMATION

In addition to regulations and standards, other actors strongly influencing the production and management of environmental information are those that organise information into systems. Some examples of organisations and systems of this kind are CAS[110] (Chemical Abstracts Service) from the American Chemical Society and EINECS[111] (European Inventory of Existing Commercial Substances) and IUCLID[112] (International Uniform Chemical Information Database), both from ECB.

Other forums in which environmental product information is addressed include various projects under the EU COST programme[113] (European Cooperation in the field of Scientific and Technical Research), publicly available life cycle inventory databases such as the Swiss EcoInvent[114], the scientific and academic society SETAC[115] (Society of Environmental Toxicology and Chemistry) and the UNEP/SETAC Life Cycle Initiative[116] (United Nations Environmental Programme and SETAC).

1.4 Gap and needs analysis

The gap analysis of the report concludes that to produce valuable output data, the methods and tools for environmental overview of product life cycles require costly input data, but that there is too little environmental data available. It is costly to acquire data. This is not generally understood by experts, industry and those developing and using methods and tools. There is no common definition of "environmental", so the concept is too wide and databases and information systems are too often built on the basis of specifications that are too broad and unrestricted. The result is that resources are expended and some new knowledge is acquired. But the information system is not optimised for specific users, and it is often costly to attract users to badly designed environmental information systems. Hence, the systems are not used by those who might need them. These are the main problems forming the basis for the gap analysis below, which is also the foundation for the contents of this report.

[109] Verfaillie H, Bidwell R (2000), *Measuring eco-efficiency - a guide to reporting company performance*, World Business Council for Sustainable Development, http://www.wbcsd.ch/web/publications/measuring_eco_efficiency.pdf.
[110] CAS, http://www.cas.org/.
[111] ECB, *European Inventory of Existing Commercial Substances (EINECS)*, viewed at http://ecb.jrc.it/existing-chemicals and http://ecb.jrc.it/esis/esis.php?PGM=ein&DEPUIS=autre.
[112] ECB (2001), *IUCLID – International Uniform Chemical Information Database*, European Commission, Joint Research Centre, Italy, available at http://www.jrc.it.
[113] COST Action 530, www.empa.ch/cost530.
[114] EcoInvent, http://www.ecoinvent.ch.
[115] SETAC (Society of Environmental Toxicology and Chemistry), http://www.setac.org.
[116] UNEP/SETAC, http://www.uneptie.org/pc/sustain/lcinitiative/home.htm.

1.4.1 Gaps identified from IMI experience

Extensive experience from the IMI project portfolio and history (see section 1.3.2) pinpoints the lack of relevant data, but also the lack of understanding about this. Most project budgets underestimate data acquisition, which is given too little attention by the participants, starts too late, has too low status, fails to meet targets, drifts over deadline, and fails. This occurs whether the participants are environmental experts or laymen or whether they are employed in industry, consultants or university academics.

Project participants tend to think that databases can be filled with data before the data need is defined. For example, project participants often want an LCA database to be filled with all LCA data before it is decided which LCA studies to perform. They often expect someone to find all environmental product data before the project has defined which environmental product aspects to consider, and they tend to expect someone to collect data on all environmentally relevant chemical and physical properties of substances before the project has determined how environmental consequences should be modelled. Moreover, project participants are inclined to believe that any data can be requested, that when a request is formulated, the data requested is actually out there somewhere, waiting to be collected.

Most project participants also think that data is good, and that it does not need to be documented, since 'this database is just a prototype', 'it takes too much time' 'nobody will examine it in detail anyway', and so on. And since data is therefore often badly documented, it cannot be reviewed and interpreted; and since it cannot be interpreted, it cannot be understood nor thus reused.

Project participants tend to think that data formatting does not concern them, that they are entitled to spend a large portion of their budget and to put the results of inventories, calculations and expertise into ad hoc tables and files they have themselves devised, so that nobody can make use of them again. Projects and people invent data formats without any idea of the cost of maintaining them. Not including the development cost of €0.5m, the cost of maintaining SPINE since 1993 is in the region of €5m - €50m, including education, training, software development and testing, user feedback, adaptations with impact assessment, design for environment, environmental management systems, etc.

1.4.2 Clarification of function and purpose of the information system

It is a well-known fact that building and measuring the quality of an information system requires that the function and purpose of the system be clearly understood[117]. The reference material for this report refers implicitly to function and purpose, but no clear overview is presented. We introduce explicit functions and purposes in this report by proposing that environmental information is always for decision making, and by identifying explicit users of each type of information.

[117] Hawryszkiewycz I T (1994), *Introduction to Systems Analysis and Design*, Sydney University of Technology.

1.4.3 Clarification of user requirements

To assess whether an information system achieves its potential, all intended users must be described and their requirements understood. No complete mapping of all intended users and user perspectives was presented in the reference material for this report. Many different users were mentioned, but not in a clear, comprehensive and consistent form. For example, the report "*Kunskap om produkters miljöpåverkan - tillgång, behov och uppbyggnad av livscykeldata*" identifies interpretation of environmental data as an area in need of attention[118]. Hence, the previous material provided no clear user and user requirements overview. We chose to address this by introducing four realistic user categories, and a handful of perspectives commonly adopted by users when assessing the environmental performance of product life cycles. Information format must also be considered, to ensure that information is useful for many uses and users. An overview of formatting needs is given in section 4.2.3.

1.4.4 Distinguishing between information input and output of methods and tools

To identify primary data of methods and tools one must distinguish between the data each method and tool needs as input and the data it produces as output. This distinction was not found in most of the reference material for this report, and none of the material included an overview of the common data input and output of the various methods and tools. We chose to address this by specifying data input needs for each method and tool, and proposing how primary data may be structured for general use as required by the methods and tools presented.

Some situations require several tools to be used together to find the information needed[119]. But we could not find any information in our reference material describing how use of different tools could be integrated in practice. For this reason, chapter 3 surveys the way available tools and methods work together, including a description of tools providing data for other tools.

1.4.5 Clarification of scope of environmental data and information

Any information and data are potentially "environmental", since environmental aspects are universal, from product weight and aerodynamic properties, to biological sensitivity and global warming, as well as environmental priorities and legislation. There is much discussion of data gaps in our reference material. Data on the use phase of products and data on environmental impacts, particularly data on human and ecotoxic impacts, are inadequate[120]. Data of this kind are needed for a life-cycle overview of products. Another data gap concerns material flow statistics[121],

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118 Naturvårdsverket (2002), *Kunskap om produkters miljöpåverkan: tillgång, behov och uppbyggnad av livscykeldata*, Swedish EPA Report 5229, page 85.

119 Naturvårdsverket (2002*), Kunskap om produkters miljöpåverkan: vad ger dagens statistik?*, Swedish EPA Report 5231, page 17.

120 Naturvårdsverket (2003), *Att mäta produkters miljöbelastning*, Swedish EPA Report 5269, chapter 4

121 Naturvårdsverket (2002), *Kunskap om produkters miljöpåverkan: vad ger dagens statistik?*, Swedish EPA Report 5231, page 14.

needed to monitor the use of materials in the industrial society using statistical methods.

To help to identify a data gap or to understand data availability we chose a definition based on the assumption that environmental data are used for defined environmental decisions or assessments. We found no adequate definition of the environmental data needed as a basis for decisions in the material we studied; without a proper definition it is impossible in practice to identify common primary environmental data. In chapter 4.4 we also propose a structure to aid understanding various kinds of available and non-available data sources.

1.4.6 Absence of consensus and coordination

Systematic environmental policy and protection requires consensus and coordination between actors at international, national and regional level. The report "*Kunskap om produkters miljöpåverkan - tillgång, behov och uppbyggnad av livscykeldata*"'[122] identifies the need for consensus and coordination at organisational level, and also suggests a model for cooperation with the actors involved to develop an effective data supply providing information about the environmental impact of products. Since that proposal provides users of data for LCA purposes (e.g. site-specific or generic process data), in addition to all the various environmental data needs, it should be noted that there are many existing forum for cooperation and consensus that could be used much more efficiently than at present. Moreover, different kinds of agreement are best achieved at different geographical and organisational levels. Agreements on methods and formats, for example, should be achieved within ISO[123] or CEN[124] at international level, and agreements on indicators and nomenclatures are best established at national level via for example the national EPAs, or in a sector, perhaps using sector associations. An important addition to this model is that scientific groups such as SETAC[125] and networks such as UNEP/SETAC[126] exist, which, combined with national competence groups, should develop and improve the results brought into the consensus process. To reduce the burden on suppliers of information, it is also important to reach a consensus among authorities and industries concerning the extent, reporting and documentation of environmental data[127].

[122] Naturvårdsverket (2002), *Kunskap om produkters miljöpåverkan: tillgång, behov och uppbyggnad av livscykeldata*, Swedish EPA Report 5229.
[123] http://www.iso.org/.
[124] http://www.cenorm.be/cenorm/index.htm.
[125] http://www.setac.org/.
[126] http://www.uneptie.org/pc/sustain/lcinitiative/home.htm.
[127] Naturvårdsverket (2002), *Kunskap om produkters miljöpåverkan: tillgång, behov och uppbyggnad av livscykeldata*, Swedish EPA Report 5229, page 19.

2 User categories and perspectives for overviewing product life cycles

2.1 Introduction

This report deals with environmental data and information about product life cycles. Dealing with all information about everything would be too great a task, so some kind of delimitation is needed. There are many ways of limiting scope, such as:

- looking at the world from a single methodological viewpoint, e.g. life cycle assessment or waste management; or
- from the viewpoint of specific materials, e.g. chemicals or scarce materials; or
- from the viewpoint of user relevance, e.g. for different sectors or different types of decision.

We have chosen to limit the scope to the viewpoint of user relevance. This is the viewpoint of those actually using environmental data and information, focusing solely on the information these users want. The disadvantage of this kind of delimitation is that to satisfy the needs of real users, many methods and tools will have to be dealt with simultaneously, and problems with data availability and formats will be real and discouraging. The advantage is that everything dealt with in the report will be relevant to real users, i.e. not only methods and tools but also primary data, data formats, integration of methods and tools and information systems.

Hence, we categorise environmental information users according to their positions and roles (section 2.2), and categorise reasons for environmental overview of product life cycles (section 2.3).

2.2 Categories of users who overview product life cycles

As illustrated by the short interview responses in section 1.2.1, some users need large quantities of detailed information; others need comparative information; while yet others need reliable statements or even labels. This illustrates one of the major difficulties in identifying the necessary common primary data for product life cycle overviews: different users have widely differing needs. These needs vary between sectors and between roles in organisations and in business situations. Users may be categorised in different ways, depending on purpose. In this report we introduce four user categories, independent of sector, but related to business structures of supply chains, consumers, societal experts and policy makers at various levels. We base the categories largely on degree of expertise, time to spend on interpreting the information, and whether the user uses the information to produce new information (such as assessment reports, policy statements, rules or recommendations), or whether he mainly takes decisions about the physical world (such as design, investment or purchase decisions). See Table 1.

User categories	Description of user type	Degree of expertise	Time to interpret	Use of information
Science and expertise	Deep interest in and understanding of many aspects of environmental information.	Environmental expert	Weeks, months, years	New information
Setting rules, policy, legislation etc	Definer and decider of acceptable behaviour and products for society, businesses, professions, consumers etc.	General expert	Days, weeks, months	New information
Professional decisions	Environmental information as a professional tool. Decisions may have legal or other implications.	Purchasing/Technical expert	Minutes, hours, days, weeks	Physical world
Everyday actions	Occasionally facing different environmental information as layman. Decisions have no legal implications.	Layman	Seconds, minutes	Physical world

Table 1. Sector-independent classification of users of environmental information for overview of product life cycles.

Detailed descriptions of the four different user categories:

- *Science and expertise*: As information users, scientists and experts perform deep and systematic analysis and assessment of all potentially relevant information about a subject from as many different angles as possible. Objectives and scope may be defined, but since the end result is not known when the work starts, these limitations may well change during the study.
- *Setting rules, policy, legislation etc*: A framework of legal limitations, rules, policies, targets etc. must be established to help decision makers and harmonise decisions of individual decision makers and their consequences. The establishment of this framework is based on scientific assessments, political discussions, negotiations, conclusions and various types of resolution, based on a wide range of environmental information. That information consists of recommendations and expert reports analysing the environmental impact or risk due to a specific substance, action or strategic decision, for example. To actually impose a rule based on the contents of recommendations in impact or risk assessments, the information must be accompanied by an assessment of the impact of setting the rule itself, e.g. the legal, economic or practical consequences of choices of substance use in products, management actions and business strategies.
- *Professional decisions*: Product designers, professional procurers, production managers, waste managers, eco-label reviewers, financial or insurance appraisers and others are obliged to take many environmental decisions. To

ease and harmonise the consequences of these individual decisions, a framework of legal limitations, rules, policies, targets etc. often exists as a guide (set by the user category *Setting rules, policy, legislation etc.*). The actual layout of this information includes black, grey or substitution lists for material choices, green procurement guidelines for professional procurers, lists of key environmental aspects for environmental production managers, classes of hazardous waste and waste treatment plans for waste mangers, target or limit values for eco-label reviewers. To act in accordance with the rules or policies, it is important that the information be relevant to the actual decision-making situation. A designer should be guided on aspects of design choices, a professional procurer on procurement choices, etc.

- *Everyday actions*: It is assumed that many important environmental decisions are taken by non-experts in situations where environmental issues have no intrinsic value, such as when consumers buy cars, clothes, food or television sets, or where employees are told to act in an environmentally friendly way in their day-to-day work. No extra time can be spent on the decisions, and no or little additional education or training is given to support more environmentally friendly decision making. Hence, the information must be simple to read and to grasp. Examples include simple situations such as sorting office or household waste, clear recommendations to turn off unused electric equipment, emphasis of environmental benefits when marketing public transport, expert review of eco-labelling of products and services that are less easily assessed by simple rules.

These user categories are introduced with a view to scoping the studies on environmental information, methods and tools and primary data in this report, and to provide a basis for deciding priorities between various user needs and requirements. For example, in chapter 5 it will be argued that the two categories - *Science and expertise* and *Setting rules, policy, legislation etc.* - are not end users of an environmental information system, but are instead components of that system. The policy makers makes decisions however which indirectly can affect product design etc. The real end users are found in the user categories *Professional decisions* and *Everyday actions*, since they make decisions that make changes in the real world, such as design, procurement or consumption of actual products or services. The report thus argues that information is intended for decision making, and that environmentally important decisions involve physical action meant to prevent environmental deterioration and risk and to promote sustainable development.

2.3 Reasons for product life cycle overview

This subchapter is a condensed list of reasons for users to gain an environmental overview of product life cycles. The list has been compiled in response to the lack of explicit user requirements in the reference material (see section 1.3.1). User requirements are crucial for selection of truly relevant methods and tools for the analysis presented in chapter 3, for the further analysis of primary data in chapter 4 and for the design of the information system in chapter 5.

The subchapter is divided into five perspectives from which people overview product life cycles for various reasons:

- *Purchasing products* - assessing a product as the prospective owner of a product or facility, for example.
- *Designing products* - assessing a product from the perspective of being able to improve its design.
- *Analysing content of product* - assessing the material contents of a product for the purpose of overviewing the environmental impact of choice of materials.
- *Considering risks of product* - assessing a product in terms of the risks it poses or its ability to cause harm over its life cycle.
- *Societal consequence of product* - assessing a product based on the environmental impact of its large-scale production.

The following five subsections are based on these perspectives, and the text in each subsection contains numerous references to expressions of explicit user requirements. Sections 2.3.1 to section 2.3.6 provide the necessary structural support for identifying information requirements for further analysis in this report.

2.3.1 Purchasing products

Business transactions, such as purchase of products for professional use or consumption, exert a strong influence over business behaviour and industrial systems. A well-informed buyer may predict how environmental factors will affect the economic aspects of buying and using the product[128,129]. These factors may relate to any stage of the product's life cycle. For instance, the resources needed to use the product may become scarce and therefore more expensive, or the product may contain hazardous materials that are likely to be affected by regulations resulting in higher prices, a ban on use, lower second-hand or scrap value, etc. Since purchasing involves ownership and use of a product, the life-cycle stages considered on purchase are safety aspects during the use phase[130, 131] and partly the end-of-life phase[132].

[128] Smith W and Kelly S (2003), *Science, technical expertise and the human environment, Progress in Planning*, Volume 60, Issue 4, November 2003, pp 321-394.

[129] Spreng D (2004), *Distribution of energy consumption and the 2000 W/capita target*, ARTICLE Energy Policy, In Press, Corrected Proof, Available online 24 June 2004.

[130] Flynn A and Kessler R (1992), *A Consumer Guide to Safer Alternatives To Hazardous Household Products, Part 2, (Take Me Shopping Original Edition)*, Hazardous Waste Management Program, Office of Toxic and Solid Waste Management, Department of Planning and Development, Santa Clara County, California, revised 1992.

[131] Berthold-Bond (1990), Clean and Green: The Complete Guide to Non-Toxic and Environmentally Safe Housekeeping, Ceres Press.

[132] Stø E, Strandbakken P, Throne-Holst H and Vittersø G (2004), *Potentials and limitation of environmental information to individual consumers*, National Institute for Consumer Research, Norway.

Buyers with knowledge of and concern for the environment may be prepared to pay a higher price for environmentally friendly products[133, 134, 135] , but only if data on environmental alternatives are made available[136,137]. Company purchases may be guided by policy, goodwill or external company image[138]. Policy commitments may include green purchasing or green procurement as a strategic tool primarily intended to control the environmental performance of the supply chain[139, 140], which is now an integral concept in logistics literature[141]. Purchase requirements can also be an indirect result of other proactive environmental tools such as eco-design[142].

Legislation may lay down explicit environmental requirements for procurement. Ownership of the product may entail environmental responsibilities. One example is the US Toxic Substances Control Act (TSCA) and US EPA Code of Federal Regulations[143], which impose environmental and safety obligations on importers of chemical substances, mixtures, or articles containing chemical substances into the United States. The EU has similar regulations on chemicals, e.g. the Swedish Environmental Code, the forthcoming REACH[144], etc.

A buyer might not possess or need detailed knowledge of all environmental consequences if the environmental burden of the product is instead included in its price as an "internalised" external cost. Hence, the buyer may consider the environment indirectly[145]. Examples of this are differential taxes based on environmental classification of cars[146,147,148], tax increase on fuel due to CO_2 emissions[149], or a deposit that is refunded when the used product is properly disposed of[150].

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133 Arvola et al. (2000), *Ekologiska livsmedel – konsumenternas attityder, vanor och värderingar*, Fakta Jordbruk 2000:16.

134 Fasth E-M (1998), *Vi tar soporna i bilen*, Vår Bostad 1998:9.

135 Wilk R,(1999), *Towards a Useful Multigenic Theory of Consumption*, European Council for an Energy Efficient Economy.

136 Skattebetalarna, http://www.skattebetalarna.se/.

137 Sanne C (2002), *Willing consumers – or locked-in Policies for a sustainable consumption*, Urban Studies, Royal Institute of Technology (KTH), Stockholm, Sweden.

138 Emtairah et al (2002), Who creates the market for environmental-friendly products?, IIIEE for Swedish EPA.

139 Walton S V, Handfield R B, Melnyk S A (1998), *The green supply chain: Integrating suppliers into environmental management processes.* Journal of Supply Chain Management 34 2, pp. 2–11.

140 Ofori George (2000), *Greening the construction supply chain in Singapore*, European Journal of Purchasing & Supply Management, Volume 6, Issues 3-4, pp 195-206.

141 Hamner B, del Rosario T (1998), *Green purchasing: A channel for improving the environmental performance of SMEs*, Workshop on Environment Policy, Globalisation and the Environment: New Challenges for the Public and Private Sectors, Paris, 13th and 14th November 1997.

142 Dewulf W, Duflou J, Ander Å (2001), *Integrating Eco-Efficiency in Rail Vehicle Design*, Leuven University press.

143 US EPA (2004), 40 CFR Part 707.20 General Import Requirements and Restrictions" and 19 CFR sections 12.118 through 12.127 and 127.28 amended Code of Federal Regulations, Toxic Substances Control Act (TSCA) Section 13 - Entry Into the Customs Territory of the United States.

144 European Commission (2001), White paper – Strategy for a future chemicals policy.

145 Baumol W J, Oates W E (1988), *The Theory of Environmental Policy* (2nd edition), Cambridge University Press, Cambridge.

146 Vägverket (2003), *Vägledning upphandlingskrav 2003-10-06 Miljö och trafiksäkerhet*.

147 Konsumentverket (2002*), Riktlinjer för information om nya personbilars bränsleförbrukning, koldioxidutsläpp och miljöklass,* KOVFS 2002:02, ISSN 0347-8041.

148 Naturvårdsverket (2000), *EU - Fuel and vehicle tax policy*, Swedish EPA Report 5084.

149 Naturvårdsverket (2000), *Koldioxidrelaterad skatt på bilar*, Swedish EPA Report 5187.

150 Naturvårdsverket (2002*), Samla in, återvinn! Uppföljning av producentansvaret för 2001, Men också mycket mer…*, Swedish EPA Report 5237.

One type of business transaction that shifts ownership responsibility is trade in various kinds of business risk, such as stocks, business shares, or insurance. Poor environmental performance may have an adverse impact on the business and its finances. Penalties includes fines, increased liability to environmental taxes, falling land values, loss of brand value, loss of sales, consumer boycotts, inability to secure financing, loss of insurance cover, contingent liabilities, law suits and damage to corporate image.[151] Banks and insurance companies also reduce their own financial risk by evaluating the environmental risk of their customers.[152] It is well known that a company can suffer financially from environmental burdens. One example is the huge cost of asbestos-related health liability incurred by ABB following its acquisition of Combustion Engineering[153] in the US. All deleterious health effects relate to the period prior to ABB's acquisition.

2.3.2 Designing products

Products and services may be designed in many ways with widely differing environmental performance. It is sometimes claimed that 80 per cent of the environmental impact of a product is decided as early as the design phase[154]. Hence, those engaged in design and development make choices having a great environmental impact. This section exemplifies environmental information relevant to product design.

Regulations, directives and other legislation lay down explicit requirements for product design. For example, the use of hazardous materials is banned in most products[155]. Governments use these regulations as a means of controlling manufacturers, not to produce products that place a heavy burden on the environment now or possibly in the future.

Professional customers in the public and private sectors express specific requirements for products[156]. This is particularly true of public sector customers, since they represent many people. They also often act in line with government directives. For example, the city of Gothenburg has been using the Gothenburg model for green purchasing since 1989[157]. This model sets environmental standards for products and suppliers. Specific examples of this model are that paper must be free of chlorine, and new car, bus or truck tyres must not contain poisonous

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151 Johnson S (2004), *Environmental management accounting*, viewed at http://www.acca.co.uk/publications/studentaccountant/1073480.

152 Naturvårdsverket (2000), *Vem behöver miljöredovisningarna?*, Swedish EPA Report 5058.

153 http://www.abb.com/global/abbzh/abbzh251.nsf!OpenDatabase&db=/global/abbzh/.abbzh250.nsf&v=553E&e=us&url=/global/seitp/seitp202.nsf/0/0C00385E709FB34BC1256F5F001EFFA8!OpenDocument.

154 Emtairah et al (2002), *Who creates the market for environmental-friendly products?*, IIIEE for Swedish EPA, Appendix 4.

155 http://www.dantes.info/Tools&Methods/Othertools/othertools_EU_legis.html and http://europa.eu.int/eur-lex/en/index.html.

156 Jönsson (2000), Communicating the environmental characteristics of products: the use of environmental product declarations in the building, energy and automotive industries , Lund, IIIEE Dissertations 2000:5.

157 http://www.upphandlingsab.goteborg.se/english.asp?nid=5.

'HA' oils as additives[158]. These purchasing requirements are partly intended to influence product design and development in the supply chain.

Private consumers generally have a complex and emotional behaviour when selecting a product, and eco-friendliness is often a decision criteria which is much lower prioritized than for example prize, quality and function[159]. Consumer product design is to a large extent based on implicit market requirements, often formed by trends, image, branding and cultural phenomena. Early identification of these implicit requirements is important, since it may determine how successful a product will be on the market. However, it should be stressed that consumers also have explicit environmental requirements on products, such as life cycle cost in terms of energy consumption for cars and refrigerators.

Manufacturers may have responsibilities for products after they are sold, and this may influence product design. For instance, the General Product Safety Directive[160] imposes responsibility on manufacturers for product safety during use, and under the European ELV Directive[161], vehicle manufacturers are responsible for recycling their products. Producer responsibility for electrical and electronic products has also been extended to include end-of-life treatment. For example, Ericsson has assumed responsibility for recycling and disposing of its products, and is developing what it calls "a proactive end-of-life (EOL) treatment programme"[162]. Even if no legislation places responsibility for potential environmental problems on a manufacturer, it will tarnish the company's green image and cost it money if any environmental problems relating to the use or disposal of a product are linked with the company's name. Hence, the product development process must also eliminate any environmental problems that may occur when using or scrapping the product.

The scarcity of some resources must be considered in the product design phase. This is particularly true if the product may be sold in large numbers. For example, platinum, which is used in catalytic converters, and gold, which is used in electronic equipment, are both scarce and expensive. Knowledge of how to re-use materials or use alternative materials is needed to avoid designing products containing scarce or relatively scarce materials. This means knowing how to design a product so that it easily can be disassembled and recycled, and knowing how to use recycled materials. The same rationale applies to energy-consuming products or production processes, since energy prices increase because energy reserves are finite[163]. Hence, it is important to possess information and knowledge about energy, material and recycling efficiency when developing products.

A good example of where environmental concern has changed product design attitudes and has brought about tangible change is in the shipbuilding and shipping

[158] http://www.upphandlingsab.goteborg.se/admin/actions/upload2/uploads/map9/goteborgs_modellen.pdf.
[159] Stø E, Strandbakken P, Throne-Holst H and Vittersø G (2004), *Potentials and limitation of environmental information to individual consumers*, National Institute for Consumer Research, Norway, p 12.
[160] European Council (1992), Directive 92/59/EEC on General Product Safety.
[161] European Commission (2000), Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of life vehicles.
[162] Ericsson (2000), *Environmental report 2000*, page 17, viewed at http://www.ericsson.com/sustainability/download/pdf/envir00rev.pdf.
[163] UN (1997), Kyoto protocol to the United Nations framework convention on climate change.

industries, where double-hull vessels are replacing those with single hulls. This change in attitude follows numerous accidents in which large amounts oil and other chemicals have spilled into the sea and caused extensive environmental damage[164].

Environmental considerations are an integral aspect of the functionality of some products, such as water purification equipment or catalytic converters. Since these products are designed to improve the environment during use, the designer may be under the illusion that the products are implicitly good for the environment. To determine whether this is true, the designers must ascertain whether the product improves the local environment while burdening the global environment, for example. One example of such products is filters for flue gas treatment, which will raise the energy consumption of the plant[165]. The environmental burden is moved from the flue exhaust to another point in the product life cycle.

2.3.3 Analysing product content

The environmental aspects of a product life cycle may be represented by its content. Information on constituent, material and substance contents of components, coating material, lubricants, fuels etc. is of interest for environmental assessment of a product. This information can be assessed in the light of expert knowledge, compared against lists of rules or target values, or tested against material policies or a certain eco-label criterion. This will demonstrate reasons and ways to overview material and substance contents of products.

Material and substance content may be assessed according to the risk that they will cause harm in various ways. This is described in detail in the next section.

Decision makers at various stages of a product life cycle may have environmental or economic reasons for ensuring that a product or component does not include scarce materials. The economic reasons may be that the future cost of a given component will be substantially higher, which may in turn lead to higher costs for the business of the decision maker. Examples are the search of alternative fuels by the automotive industries owing to declining oil reserves, the availability of platinum for fuel cell development[166], and the paradoxical dilemma of enhanced efficiency of solar cells doped with a scarce element such as cadmium. Other materials that are not scarce at present may become so. For example, until recently steel was not regarded as a scarce resource, but technical development in countries like China has rapidly increased the rate at which the world's resources of virgin steel are depleting[167].

At various stages of a product's life cycle producers, users and waste managers are interested in knowing the actual content of the product for economic valuation purposes, such as its recycling value. From the viewpoint of producer

164 Committee on Oil Pollution Act (1990), *Double-Hull Tanker Legislation: An Assessment of the Oil Pollution Act of 1990*, (Section 4115) Implementation Review, National Research Council, viewed at www.naval-technology.com.

165 Gäbel K (2001), *A life cycle process model*, CPM Report 2001:10.

166 AEA Technology (2003), *Platinum and hydrogen for fuel cell vehicles*, AEA technology, Harwell, UK.

167 Wäingelin J (2004), *Stålbrist hot mot bilfabriker i Europa*, Dagens Industri 9 November 2004.

responsibility, the producer needs to appraise the cost of scrapping the product[168]. This cost is based partly on the material content of the product, since the recycled material might be sold by the waste management enterprise.

Long-life products, such as buildings and energy and transport infrastructure, are intended to last longer than the careers of the people who constructed them, longer than the policies, the politics and the regulations under which they were built. It is therefore also likely that will outlive current environmental knowledge. Material content is therefore of interest for future valuation of, and responsibility for, these products, even if some of the information is not known at present. Environmental information systems like the international material data system (IMDS[169]) of the automotive industries, and the similar Swedish building industry system (BASTA[170]) have been designed to supply and maintain information about material contents of products in the future.

To develop environmental product policies, assess environmental risks or for regulatory reasons, the material content of a product or a family of products may need to be analysed. This requires a compilation of the product's material content. One sector interested in resolving this information problem is the electronics industry, where much of the material content of products is not very well known[171].

2.3.4 Considering product risks

A product or service may give rise to a health or environmental risk or harm, directly or indirectly. Risk or harm may be partly due to product properties, such as material content, design, function and may occur partly because of the situation in which the product is manufactured, transported, operated, waste treated [172] etc. Therefore, to assess the risk of a product causing harm, contextual information may also be needed. This section demonstrates reasons for needing environmental information for risk assessment.

People in general are interested in knowing about substances in products so they can avoid risks of allergy and cancer, for example[173]. This is particularly true of chemicals in the working environment, e.g. in the chemicals industry[174]. Vehicle exhaust fumes, dispersal of chemicals in everyday products and tobacco smoke expose people to a large number of allergens[175]. Products may also produce hazardous emissions during processing[176], use[177] or end of life[178] due to their material content. The products themselves may cause harm to the environment. The fact that

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168 Lindhqvist T (2001), Extended Producer Responsibility for End-of-Life Vehicles in Sweden - analysis of effectiveness and socio-economic consequences, IIIEE Reports 2001:18, Lund University, Sweden.

169 IMDS, http://www.mdsystem.com.

170 Byggsektorns kretsloppsråd (2003), *Byggsektorns Miljöprogram 2003* http://www.bastaonline.com.

171 Ericsson (2003) Ericsson and the Environment: Working to make a sustainable difference, Ericsson Enterprise AB.

172 KemI (2004), *Information om varors innehåll av farliga kemiska ämnen*.

173 WHO, http://www.who.int/.

174 American Chemistry Council, http://www.responsiblecare-us.com.

175 Peterson G (1999), *Kemisk miljövetenskap*, Chalmers University of Technology.

176 Forrest M J, Jolly A M, Holding S R, Richards S J (1995), *Emissions from Processing Thermoplastics*, ISBN 1-85957-041-0.

177 Henneuse C, Pacary T (2003), *Emissions from Plastics*, Rapra Technology Ltd.

178 ARGUS (2000), *The behavior of PVC in landfill*, European Commission DGXI.E.3.

a product may pose a direct threat owing to its content concerns the waste management industry, for example, where workers may be exposed to hazardous materials[179].

Biodiversity directly affects our quality of life, through physical, educational, social and aesthetic assets. As a consequence, individuals, NGOs and environmental agencies express concern about environmental harm in terms of increased loss of biodiversity of dead seas, mass wildlife kills, etc.[180,181,182].

Despite growing support from the chemicals industry and environmentalists for a phase-out of several highly toxic and persistent substances, new compounds continue to be introduced into global commerce at a rapid rate. The health effects of these substances often become apparent only long after their introduction[183]. Many scientific studies have shown the extent of environmental problems caused by hazardous chemicals/products and also the need for information about their life cycle. Polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/DFs) remain an environmental problem in Sweden, for example, although the use and manufacture of PCBs have been banned for decades and the release of PCDD/DFs has decreased significantly[184].

Environmental accidents and disasters have made people even more concerned about environmental risks. One example is the disaster in India in 1984 when poisonous gas leaked from a factory and killed over 7,000 people in the village of Bhopal[185].

European legislation lays down requirements for the environmental and human risks posed by chemicals and products. There are also national strategies for specific chemicals, e.g. to phase out the use of mercury, cadmium and lead[186]. In Europe, manufacturers and others marketing chemical products intended for professional use must provide information about the product on a Safety Data Sheet (SDS). An SDS details hazardous properties of chemical products, ecotoxicity, fire safety, safe handling, transport and storage for a specific product. SDSs must meet the requirements of EC Directive 91/155/EEC and present information on a product's health and environmental hazards under 16 compulsory headings. Producing an SDS involves collecting all information about the product under the headings and presenting the information in the SDS format.

The EU regulatory framework requires that a risk assessment be conducted for existing chemicals on the market before 1981 and having particular priority. This is also required for new chemicals before they are released on the market. The Technical Guidance Document (TGD) on Risk Assessment for New and Existing

179 Andersen Aage Bjørn (2001), *Worker safety in the ship-breaking industries*, International Labour Office, Geneva.
180 Greenpeace, http://www.greenpeace.org.
181 Primal Seeds, http://www.primalseeds.org.
182 IUCN - The World Conservation Union, http://www.countdown2010.net.
183 Worldwatch institute, www.worldwatch.org.
184 Bjerselius R, Aune M, Darnerud P O, Törnkvist A, Glynn A, Larsson L (2004), *Persistent organic pollutants (POPs) in fish from the Baltic Sea*, Sweden, 2000-2002.
185 Dow, http://www.dow.com/commitments/stewardship/index.htm.
186 KemI, http://www.kemi.se.

Substances[187] details the methods to be used for risk assessment under European regulations. The scope of the risk assessment covers emissions and resulting environmental impact at each stage of the life cycle of a chemical product, from production, through processing, formulation and use, to recycling and disposal. The forthcoming chemicals policy entitled Registration, Evaluation, Authorisation of Chemicals - REACH[188], is intended to become the overarching organisational legal requirement for risk assessments of new and existing chemicals in the European Union. It is more comprehensive than previous regulations and will affect companies producing chemicals as well as their customers and suppliers.

2.3.5 Societal impact of products

The life cycle of most industrial products has environmental impacts in society beyond the intentions of the product designers, manufacturers, suppliers and buyers. These unintentional consequences result from the large material and energy flows of industrial systems, coupled with global adaptation to mass consumption, industrial-scale raw material abstraction and goods production, mass-production for consumer markets, global logistics etc. Reasons for assessing environmental impacts on society are set out in this section.

In Europe, following the Amsterdam Treaty of 1997, the principle of sustainable development has been incorporated in the EU constitution as one of the goals of the European Union. Responsibility for compliance with environmental laws is largely placed on manufacturers in the form of laws and regulations, such as the Polluter Pays Principle[189], the Precautionary Principle[190] etc. The Integrated Product Policy (IPP)[191] is another important pro-active tool of environmental policy. Integrated Product Policy (IPP) seeks to minimize the environmental degradation caused by products by looking at all phases of a products' life-cycle and taking action where it is most effective. The life-cycle of a product is often long and complicated. It also involves many different actors such as designers, industry, marketing people, retailers and consumers. IPP attempts to stimulate each part of these individual phases to improve their environmental performance. IPP contains a whole variety of tools - both voluntary and mandatory - that can be used to achieve this objective. These include measures such as economic instruments, substance bans, voluntary agreements, environmental labelling and product design guidelines.[192]

In a democracy, government regulations and legislation are based on what is culturally accepted. It may therefore also be expected that citizens in a democracy with environmental regulations also habitually and voluntarily apply environmen-

187 ECB (European Chemical Bureau) (2003), Technical Guidance Document in support of Commission Directive 93/67/EEC on Risk Assessment for new notified substances, Commission Regulation (EC) No 1488/94 on Risk Assessment for existing substances and Directive 98/8/EC of the European Parliament and of the Council concerning the placing of biocidal products on the market, viewed at http://ecb.jrc.it/cgi-bin/reframer.pl?A=ECB&B=/Technical-Guidance-Document/.

188 European Commission (2001), White paper – Strategy for a future chemicals policy.

189 European Union (1997), *The Amsterdam Treaty*, Article 174(2).

190 European Union (1997), *The Amsterdam Treaty*, Article 130r.

191 European Commission (2001), Green Paper on Integrated Product Policy.

192 http://europa.eu.int/comm/environment/ipp/integratedpp.htm

tally responsible perspectives to their lives and actions. The sympathies of these voters[193] are one reason that governments and political parties are anxious to be perceived as environmentally aware. For example, four out of five Swedes sort their household waste[194]; they are neither forced to do so, nor driven by strong idealism; they do so by habit. People also want to know the 'big picture' implications of their everyday actions, even though the environmental impact of any household product is too hard to fully assess in daily purchase situations and customers in fact seldom changes their habits[195].

Behaviour considered natural and sustainable for generations when our ancestors lived together in farms, small villages and early towns, now causes resource depletion or extensive environmental damage. Common sense no longer suffices to predict the environmental consequences of our behaviour. One simple example of when common sense did not work is when a reduction in food packaging for environmental reasons resulted in increased food waste with a greater impact on the environment[196]. We become confused and puzzled by the large scales of global economies and industrial numbers. Individuals keen to avoid health risks therefore willingly try to increase their own knowledge[197]. But entire societies also need to acquire new knowledge about these new large inter-connected systems for the purpose of societal learning and cultural change alone. Examples are various societal assessments, which have been made of substance and material mass flows and balances to acquire knowledge about them[198].

In addition to learning due to IPP or other initiatives, many companies introducing new products, regulatory bodies or responsible NGOs also assess the potential consequences of introducing technological innovations for mass consumption. Examples are assessments performed on mobile phones[199], video conferencing[200], genetically modified crops[201], and hydrogen and fuel cell systems[202].

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193 See http://www.democrats.org/, http://www.labour.org.uk/, http://www.sap.se/ etc.
194 Fasth E-M (1998),*Vi tar soporna i bilen*, Vår Bostad 1998:9.
195 Arvola et al. (2000*), Ekologiska livsmedel – konsumenternas attityder, vanor och värderingar*, Fakta Jordbruk 2000:16.
196 Ahlqvist E, Palm D (2000), *Förstörda varor belastar miljön och gör varan dyrare för konsumenten*, Packforsk Rapport nr 193, Uppsala University.
197 Children's Health Environmental Coalition, http://www.checnet.org/.
198 Naturvårdsverket (2002), *Kunskap om produkters miljöpåverkan - vad ger dagens statistik?,* Swedish EPA Report 5231.
199 Oiva L, Oppermann W et al. (2000), *Case study on the environmental impacts of a mobile phone*. Electronic goes Green 2000+, Berlin, VDE.
200 Rydberg T, Östermark U et al. (2001), *Life Cycle Assessment of a Videoconference - a comparative study of different ways of communication*, 13th Discussion Forum of Life Cycle Assessment. Environmental Impact of Telecommunication Systems and Services, Lausanne, EPFL.
201 SIDA (2002), *People and the Environment*, Sida bulletin 2002/02.
202 US Department of Energy, http://www.eere.energy.gov/hydrogenandfuelcells/analysis.

3 Methods and tools

3.1 Introduction

Chapter 3 presents methods and tools intended to provide an environmental overview of product life cycles, or supporting an overview indirectly by providing data, for example. The methods and tools are selected on the basis of the information for which users in sections 2.3.1 to 2.3.5 have expressed a need.

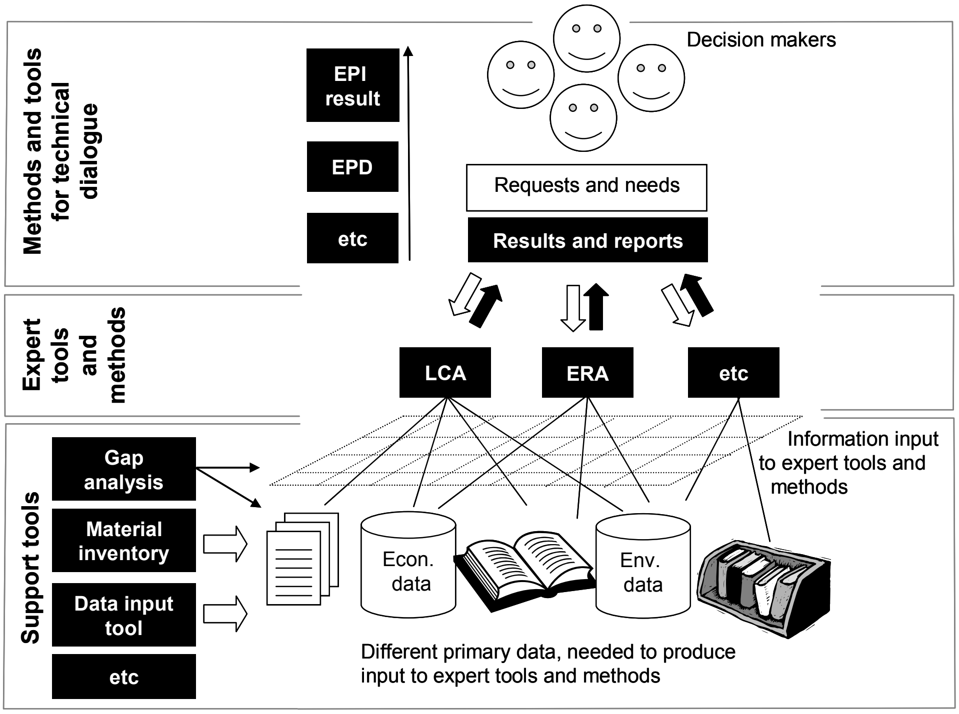

Figure 3. The tools are classified according to their intended use: support tools, expert tools and communication tools. Expert tools and methods address the requests and needs of decision makers. Support tools give information input for the expert tools. The methods and tools for technical dialogue are used to make the results from the expert tools understandable for the decision makers.

The methods and tools are assessed in particular to describe their data input needs, as well as to suggest tools to be used together or in sequence. Data input needs are specifically analysed to identify their common primary data needs, i.e. the data required by many methods and tools, and to identify the availability of that data.

The methods and tools are divided into categories according to their intended use: communication tools, expert tools and support tools. *Communication tools* are intended to simplify environmental information in different ways, so that it is understandable for the decision maker. Examples are environmental performance indicators (EPIs), various standardised data sheets and environmental declarations. *Expert tools* are intended to answer complex questions about environmental performance. They include decision support tools for procurers or designers and analysis tools for environmental experts. *Support tools* provide information input for expert tools but can also be used independently. Examples are databases, restriction lists and data input tools. Figure 3 depicts the relationship between the various tools.

The three types of methods and tools are relevant for SMEs, large corporations, countries or for international cooperation. SMEs should seek to use methods and tools that are easy to use, interpret and communicate and they should seek to share the cost of expert tools and support tools with other SMEs or larger corporations, for example. Publicly funded initiatives and large corporations should seek systematic ways of sharing data and information, perhaps by striving to harmonise environmental performance indicators.

The authors note that numerous methods and tools are available, and that it is not likely that ordinary users will themselves find the most appropriate tool without substantial expert assistance. Unfortunately, most tools also involve substantial data availability gaps. The situation would be substantially clarified by further relevance and data availability studies and assessments. The methods and tools will be presented top down from the perspective of Figure 3, beginning with "Methods and tools for technical dialogue", followed by "Expert methods and tools", and concluding with "Support methods and tools".

Editor's note: As a guide to users, the editor makes qualitative remarks on the applicability of each method or tool ("*Editor's remarks on applicability of method or tool*"). Resource demand is expressed as resources needed to establish a necessary data bank or the data supply, or resources needed to use a tool. Ease of understanding is expressed in terms of whether the method or tool can be used or understood by environmental experts, by general professionals with some environmental responsibilities or even by mainly laymen in the field.

3.2 Methods and tools for technical dialogue

There are several tools for communicating environmental issues. Presented here are life cycle interpretation, environmental performance indicators (EPIs), and data sheets and declarations.

Methods and tools for communication and dialogue are crucial to the environmental performance of any organisation. If the results of an environmental performance assessment or measurement cannot ultimately be communicated to the intended decision maker, policy maker or other stakeholder, the resources spent on the assessment will have been virtually wasted. It may have been a good learning exercise for the practitioner(s), but such reasons fall outside the scope of this report (see sections 2.2 and 2.3).

3.2.1 Life Cycle Interpretation – ISO 14043

The ISO 14043 standard describes the final phase of the standardised LCA procedure (see 3.3.3.1), in which the results are summarised and discussed as a basis for conclusions, recommendations, and decision making. The standard treats communication between the commissioner and the practitioner of the LCA study as an "iterative" (i.e. incremental) process in which the results are compared with the objectives and scope.

Life cycle interpretation includes recommendations on communication, to lend credibility to the results of the LCA in a form that is both understandable and useful for the decision maker[203].

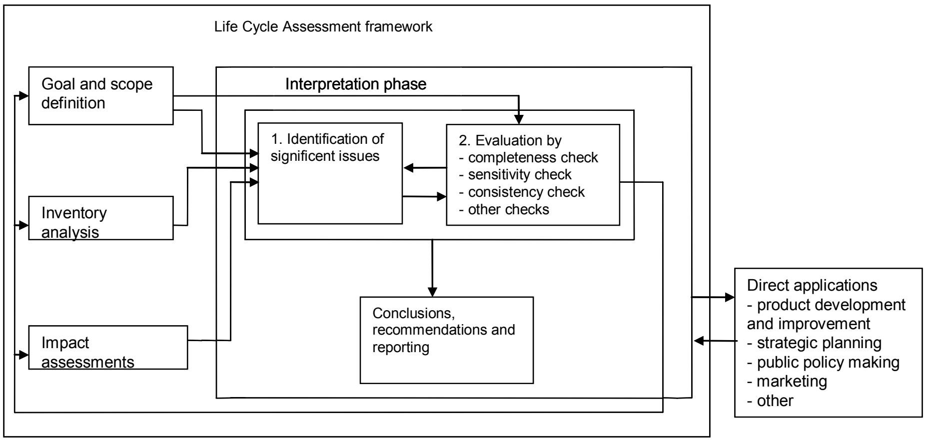

Figure 4. The life cycle interpretation phase according to ISO 14043. © ISO 2000.

The information on impact from the upstream activities in LCA studies is sometimes excessive, while on the other hand there is a lack of downstream information. This may be due to a lack of data and models for downstream activities, or the method used (see 3.3.3.4) but it may also depend on the commissioner of the study. The intended user of an LCA study may be the consumer of the product, who might not be interested in a study of the impacts caused by his own activities, but would prefer information about the environmental performance of the product cradle to gate.

3.2.1.1.1 Applications of the method/tool

Life cycle interpretation is used when LCA is used. The performer of the interpretation can be the same environmental expert that made the LCA or another environmental expert. The result of the interpretation may be an environmental product declaration or a key indicator value that is meaningful for people with little or no environmental expertise. See 3.3.3 for examples of applications.

Editor's remarks on applicability of method or tool: An LCA that is not interpreted thoroughly is not efficiently performed and its results are not fully effective. The work must be done by the person who performed the LCA together with representatives of the intended audience. The cost of preparing LCA results so that they can be interpreted by the intended audience is money well spent.

3.2.2 Environmental performance indicators (EPIs)

Indicators aid orientation in a complex world. They condense complex systems into a manageable quantity of meaningful information[204]. There are many types of

[203] International Organisation for Standardisation (2000), ISO 14043: Environmental management - Life cycle assessment - Life cycle interpretation.

[204] Bossel H (1999), *Indicators for Sustainable Development: Theory, Method, Applications*, International Institute for Sustainable Development.

indicator[205], e.g. environmental performance indicators (EPIs) and environmental condition indicators (ECIs), as defined in ISO 14031[206], sustainability performance indicators of GRI[207], the Swedish Environmental Objectives[208], eco-efficiency indicators of WBCSD[209], sustainability index criteria of Dow Jones[210], system conditions[211], etc.

Applications of the method/tool

Indicators are helpful when assessing and communicating factors in a product's predicted life cycle having potentially adverse effects on health or the environment. The ability to simplify information about a complex system, by using a selected set of indicators to describe it, is important when communicating with non-environmental experts, e.g. product designers and corporate purchasers. The organisation's policy, image and goodwill can be incorporated in the design process by converting sustainability criteria into material selection and design criteria[212]. Further examples of the use of indicators in industry are in the supply chain as a means of communication between suppliers and customers[213], and in tools for green procurement[214].

Indicators can also be used to communicate with the public, to communicate a green image to customers or people in general or to establish the market's environmental criteria and willingness to pay for green product design. In the last-mentioned case, the indicators may be "safeguard objects", for example, which are evaluated by a panel of citizens in monetary terms[215].

GRI indicators are used by several organisations[216] to measure and assess environmental performance. The advantage of using general indicators created by a global organisation is that the comparability of the company's environmental performance increases. The disadvantage is that they are not always the most relevant indicators for the organisation. The choice of indicators is an implicit statement of

[205] General environmental indicator links can be found at: http://www.pepps.fsu.edu/EI_Gen.html.

[206] International Organisation for Standardisation (1999), ISO 14031: Environmental management – Environmental performance evaluation – Guidelines.

[207] Global Reporting Initiative (2002), *Sustainability Reporting Guidelines*, http://www.globalreporting.org/guidelines/2002/gri_2002_guidelines.pdf.

[208] Sveriges Miljömål, http://www.miljomal.nu.

[209] Verfaillie H, Bidwell R (2000), *Measuring eco-efficiency - a guide to reporting company performance*, World Business Council for Sustainable Development, http://www.wbcsd.ch/web/publications/measuring_eco_efficiency.pdf.

[210] http://www.sustainability-index.com/htmle/assessment/criteria.html.

[211] Holmberg J (1995), *Socio-Ecological Principles and Indicators for Sustainability*, Ph.D Thesis, Institute of Physical Resource Theory, Chalmers University of Technology and Gothenburg University, Sweden.

[212] Flemström K (2003), *Environmental Performance Indicator (EPI), Methodology in REPID*, Chalmers University of Technology, Sweden.

[213] Manuilova A (2003), Transport and the Environment. Cellulosic Specialties in Örnsköldsvik and Stenungsund. Environmental Performance Indicators (EPIs), Report for the DANTES project, available at http://www.dantes.info/Publications/Publication-doc/EPI%20-%20CS.pdf.

[214] http://www.eku.nu/.

[215] Steen B (1999), A systematic approach to environmental priority strategies in product development (EPS). Version 2000 – General system characteristics, CPM report 1999:4, Chalmers University of Technology, Sweden.

[216] For example, http://www.sustainable.veoliaenvironnement.com/en/.

the actor's viewpoint. This information is required in communication between the performer and the commissioner of a study on environmental impact [217].

Editor's remarks on applicability of method or tool: Section 1.2.1 describes the meaning and importance of indicators. The cost of identifying and selecting indicators may be high, and this is best done by experts. But when indicators are wisely chosen, they are easy to use and easy to communicate to experts, professionals and laymen.

3.2.3 Data sheets and declarations

3.2.3.1 ENVIRONMENTAL PRODUCT DECLARATION (EPD)

An Environmental Product Declaration (EPD)[218] presents a set of quantified environmental data for a product based on information from a life-cycle assessment (LCA) according to the ISO 14040 series of standards. An EPD is a standardised (ISO 14025/TR[219]) and LCA-based tool for communicating the environmental performance of a product or system. It includes information about the environmental impacts associated with a product or service, such as raw material acquisition, energy use and efficiency, content of materials and chemical substances, emissions to air, soil and water, and waste generation. It also includes product and company information. In addition, there is a requirement for presenting a minimum of inventory data together with interpretation in an EPD, and all information should be critically reviewed[220] [221].

Applications of the method/tool

EPDs can be used to assess health and environment aspects of a product on purchase and also together with green procurement and relevant indicators, when applying green image and policy in procurement as discussed in previous chapters. EPDs can also be used when including environmental market demand in the procurement process. Users of EPDs may thus be professional decision makers such as purchasers, and also to some extent everyday consumers. In addition, the users performing EPDs for a company's products are often environmental experts.

Information on a product's environmental impact can be found in an EPD and it can therefore be used with other risk-related information such as an environmental risk assessment to assess factors about present or intended product life cycles posing a threat to the environment.

Editor's remarks on applicability of method or tool: EPDs are based on LCA, which tends to make them expensive, but the very fact that core LCA parameters are defined in common Product Category Rules (PCR) makes LCA easier. Hence, if data is available, LCAs for EPDs can be fairly cost-effective, and the formats

[217] Carlson R, Häggström S (2004), Pålsson A-C *Policy controlled environmental management work - Final report*, CPM-report 2004:10.
[218] Global Type III Environmental Product Declarations Network, http://www.gednet.org.
[219] International Organisation for Standardisation (2002), ISO/TR 14025: Environmental labels and declarations - Type III environmental declarations.
[220] Sanne K, Imrell A-M (2003), *EPD – Key to interpretation key*, DANTES report.
[221] Bogeskär M, Carter A, Nevén C-O, Nuij R, Schmincke E, Stranddorf H K (2002), *Evaluation of Environmental Product Declaration Schemes*, European Commission, DG Environment, September 2002.

prescribed by the EPD systems may ease communication and understanding, particularly for professional decision makers.

3.2.3.2 SAFETY DATA SHEETS (SDS)

A Safety Data Sheet (SDS) presents information on a product's health and environmental hazards. It also provides information on storage, safe handling, and transport.

All suppliers of chemical products are required by law to complete SDSs on hazardous chemical products. These will then be used in purchasing contexts and sent to industrial customers. SDSs meet the requirements of European Union Directive 91/155/EEC[222] and break down into 16 sections. An SDS includes information such as physical data (boiling, melting, and flash point), toxicity, health effects, first aid, reactivity, disposal, protective equipment, and spill/leak procedures[223].

Applications of the method/tool

There are many SDS applications. This section only exemplifies some of them. For instance, SDSs may be found at chemical industry websites e.g. Akzo Nobel Surface Chemistry[224]. Those SDSs contain information on product constituents. The risk status of the chemical ingredients or substances is also included. Information on how to handle a hazardous substance or product is also given. Risk assessment, SDSs, environmental impact assessments and various labels and declarations are used to assess factors in the present or intended life cycles of products having a potentially adverse effect on the environment and the health of present and future generations, including allergy and cancer; see 3.3.2.

SDSs can be used to assess health and environment aspects of a product on purchase, although more information in the form of eco-labels and various relevant indicators is often used as a complement. Whether a product emits hazardous substances at any stage of its life cycle could be assessed using a streamlined LCA to identify the emissions. This would include a risk assessment of the product, an SDS showing the contents of the product, and also information about emissions from material in different situations, e.g. in the Swedish Chemical Inspectorate classification list database.

SDS are often used to provide information for environmentally interested product designers, NGOs, and performers of environmental responsibility assessment, as well as the named professional decision makers, policy makers and environmental experts in Table 1 in this report.

Finally, SDSs, EPDs, indicator results, and supply chain tools can be used when market demands are included in the procurement process.

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[222] European Commission (1991), Directive 91/155/EEC of 5 March 1991 defining and laying down the detailed arrangements for the system of specific information relating to dangerous preparations in implementation of Article 10 of Directive 88/379/EEC, Official journal NO. L 076 , 22/03/1991 P. 0035 – 0041.

[223] KemI (1999), Product information – a guide to be consulted in the work to classify and label chemical products and when preparing safety data sheets, Swedish National Chemical Inspectorate, Report June 1999

[224] Akzo Nobel, http://www.surfactantseurope.akzonobel.com/msds.cfm?Product=93&Language=044.

3.2.3.3 ECO-LABELS

Many eco-labels for consumer products exist at both national and international level. The International Organisation for Standardisation (ISO) has developed standards for three types of label called types I, II, and III. Type I eco-labels are voluntary and based on a pass-or-fail criterion, e.g. the Nordic swan[225], the EU flower[226], and *Bra miljöval*[227]. The type II eco-label program is for the self-declaration of claims, any written or spoken environmental statement, e.g. manufacturers declare information about the environmental impact of their products. There are no third-party verification or pass-or-fail criteria. Type III eco-labels are LCA based: there are no pass-or-fail criteria but there is third-party verification for these labels.[228]

3.2.3.3.1 Applications of the method/tool

Eco-labels such as the Nordic swan, *Bra miljöval*, and EPDs can be used by consumers to assess health and environment aspects of products on purchase. Different types of eco-labels, environmental reports can also be used when producing statements on safety and low environmental risk.

Eco-labels can be used to encourage more sustainable or "environmentally friendly" purchasing patterns or habits[229].

In addition, risk assessments, SDSs, environmental impact assessments and various labels and declarations are used to assess factors in the present or intended life cycles of products having a potentially adverse effect on the environment or the health of present and future generations.

Editor's remarks on applicability of method or tool: Table 1 in section 2.2 shows that environmental laymen spend seconds or minutes on purchasing decisions in their everyday lives. Despite the risk of oversimplification, information more complex than environmental labels cannot be used in this communication.

3.2.3.4 ENVIRONMENTAL REPORTS

Environmental reporting is performed to satisfy stakeholders' environmental information requirements. The environmental information can be included in the company's annual report or published as a separate environmental report[230].

Swedish companies conducting environmentally hazardous operations subject to a permit requirement must submit an environmental report annually to the regulatory authority[231]. Other companies and organisations do so voluntarily; the contents may therefore vary and reduce the comparability of the information provided[232].

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225 http://www.emcentre.com/textile/LT_eco-labellNor.htm.
226 http://www.eco-label.com/default.htm.
227 http://www.snf.se/bmv/index.cfm.
228 European union Eco-label homepage; http://europa.eu.int/comm/environment/eco-label/index_en.htm.
229 http://www.svanen.nu.
230 Ljungdahl F (1999), *Utveckling av miljöredovisning i svenska börsbolag - praxis, begrepp, orsaker*, Lund University Press, Sweden.
231 Swedish Environmental Code; chapter 26, section 20 (Miljöbalken 26 kap. s 20).
232 Naturvårdsverket (2000), *Vem behöver miljöredovisningarna?*, Swedish EPA Report no 5058.

Some companies have sustainability reporting, including the economic, environmental, and social dimensions of sustainability[233]. The target groups for environmental reporting vary from one company to another, and include shareholders, lenders, customers, employees, neighbours. The environmental report is a means for the company to project an environmental profile and its environmental ambitions, and helps it to appear credible on environmental issues[234]. The production of an environmental report is generally included in the environmental management system.

Under the Swedish Environmental Code, an environmental report must describe the measures taken to comply with the conditions laid down in a decision granting a permit and the results of those measures. It must also contain a description of the environmental impact of the activity, including aspects other than those set out in the permit conditions. Other information relevant to the Code and its objectives may also be required[235]. The Swedish Accounting Standards Board suggests that environmental information having a direct or indirect impact on the company's potential for financial growth should be presented in the environmental report[236]. Since the contents of environmental reporting are not stipulated, it commonly also includes positive environmental news and excludes environmental information that may be perceived as negative.[237]

Applications of the method/tool

Environmental reporting is a means of producing statements on safety and low environmental risk. It can be interpreted as an environmental label for the company as a whole[238]. A study by the accounting firm KPMG shows that corporate sustainability reporting has increased over time and nearly half of the 500 largest global corporations perform sustainability reporting[239].

Environmental reporting is performed by environmental experts at the company, whereas it is intended for any stakeholder, possessing anything from expert to little or no environmental knowledge.

Editor's remarks on applicability of method or tool: The compilation of environmental reports is a good exercise for corporate environmental management teams, but much remains to be done on information management for sustainable development, as described in section 1.2.2 and Figure 2. Quality management principles are described in sections 3.4.5.2 and 4.2.2, and in Figure 12.

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233 http://www.globalreporting.org/index.asp.

234 Naturvårdsverket (2000), *Vem behöver miljöredovisningarna?*, Swedish EPA Report no 5058.

235 Swedish Environmental Code; chapter 26, section 20 (Miljöbalken 26 kap. s 20).

236 BFN (1998), *Miljöinformation i förvaltningsberättelsen*, Bokföringsnämndens uttalande U98:2.

237 Naturvårdsverket (2000), *Vem behöver miljöredovisningarna?* Swedish EPA Report no 5058.

238 Ljungdahl F (1999), Utveckling av miljöredovisning i svenska börsbolag - praxis, begrepp, orsaker, Lund University Press, Sweden.

239 KPMG (2002), *KPMG International Survey of Sustainability Reporting 2002*, KPMG Global Sustainability Services viewed at http://www.wimm.nl/publicaties/KPMG2002.pdf.

3.3 Expert methods and tools

Expert methods and tools provide analysis, assessment and decision support.

3.3.1 Decision support tools

3.3.1.1 GREEN PROCUREMENT

Green procurement, also called environmental (or green) purchasing, is a tool integrated in IPP and is regarded as a successful way of promoting improved environmental performance by SMEs. Requests by buyers for information about the environmental performance of suppliers and products demonstrate to suppliers that there are compelling commercial reasons for improving their environmental performance. It is an increasingly common practice, which is effectively greening the supply chain[240].

Green procurement is a tool for choosing between products or suppliers. The information basis is product environmental criteria such as energy efficiency, content of hazardous substances, packaging,[241] and information about the supplier's environmental performance, such as the existence of an environmental management system. Guidelines for green procurement in the EU can be found in the European Green Procurement Database[242] and in a handbook on green procurement published by the European Commission[243]. The conflicts with legal demands governing public procurement in the EU and green procurement are addressed in the document "Guidelines on greening public procurement by using the European eco-label criteria"[244].

Applications of the method/tool

Green procurement tools can be used by policy makers to inform professional decision makers such as purchasers and designers and also consumers about environmental regulations on procurement. The Swedish Committee for Ecologically Sustainable Procurement has developed guidelines and methods on the use of environmental criteria in public procurement for various product groups and also an web-based instrument for green procurement (the EKU instrument). The instrument serves as a voluntary guideline that can be used to weigh up environmental considerations when purchasing goods, services and contract services. The EKU instrument will be further developed for use in the private sector[245].

Green procurement tools can also be used by purchasers and designers at companies as a day-to-day means of implementing green image and environmental policy or including market demands in the procurement process. Many companies

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240 Hamner B, del Rosario T (1998), *Green purchasing: A channel for improving the environmental performance of SMEs*, Workshop on Environment Policy, Globalisation and the Environment: New Challenges for the Public and Private Sectors, Paris, 13 and 14 November 1997, http://www.cleanerproduction.com/misc/pubs/OECDpaper.html.

241 http://europa.eu.int/comm/environment/green_purchasing/html/general/whatproducts_en.cfm.

242 http://europa.eu.int/comm/environment/green_purchasing/cfm/fo/greenpurchasing/.

243 European Commission (2004), Buying green! A handbook on environmental public procurement.

244 http://europa.eu.int/comm/environment/eco-label/pdf/public_procurement/pubprocguide_en.pdf.

245 Miljöstyrningsrådet, http://www.eku.nu/.

now have procurement practices incorporating environmental considerations[246]. Green procurement is a means of controlling the environmental performance of the supply chain. It also strengthens the corporate environmental image[247].

Editor's remarks on applicability of method or tool: It may take months to establish knowledge and support systems at the company for a properly functioning green procurement system, but once in place it is easy to use and integrate with ordinary business principles. It should be easy to understand by experts as well as laymen. This may also be a general weakness of the system, since there is a risk of the decision base being too simplified to deal with the true multidisciplinary and multi-criteria problems of environmental decisions.

3.3.1.2 DESIGN FOR ENVIRONMENT (DFE)

Design for Environment (DfE) (also called Ecodesign) supports product developers by enhancing product design to reduce environmental impact even in the development phase of the life cycle. This includes reducing consumption of material and energy, and preventing pollution where this can be linked to product design features such as composition, combination or number of materials used.

Available DfE methods or tools can be divided into methods for identifying design goals and requirements, methods for proactive design guidance and methods for assessing the environmental performance of the product. These methods have been incorporated in many software tools[248].

Examples of DfE methods and tools

The RAVEL method

The DfE method developed under the EU-funded project RAVEL – RAil VEhicLe eco-efficient design (1998-2001) is based on product-related measurable Environmental Performance Indicators (EPIs), a useful and common material list, and is technically facilitated by a common communication format for data exchange. Examples of EPIs include recyclability, energy efficiency, quantity of hazardous materials etc. This method provides communication and measurement of environmental performance in the supply chain, and provides a connection between market requirements and product design; see Figure 5.

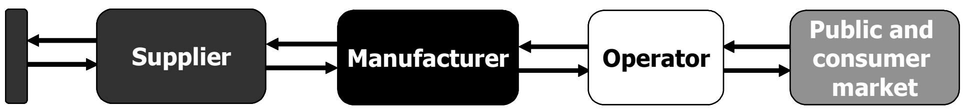

Figure 5. The methods and tools used in the RAVEL and REPID projects provide communication and measurement of environmental performance.

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246 Coca-Cola, *"eKOsystem brochure"*, viewed at http://www2.coca-cola.com/citizenship/eKOsystem.pdf and Procter & Gamble, *"Sustainability Report 2004"*, viewed at http://www.pg.com/content/pdf/01_about_pg/corporate_citizenship/sustainability/reports/sustainability_report_2004.pdf.

247 Ofori G (2000), *Greening the construction supply chain in Singapore*, European Journal of Purchasing & Supply Management, Volume 6, Issues 3-4, December 2000, pp 195-206.

248 Dewulf W, Duflou J, Ander Å (2001), *Integrating Eco-Efficiency in Rail Vehicle Design*, Leuven University press.

Another EU-funded project (REPID, 2002-2004) has developed a software application based on the method for analysing and communicating eco-efficiency of the design of any train or train component, in terms of common EPIs. The methods implemented in the railway industry also apply generally to any other sector[249]. See the examples in Appendix 1 for more information.

Sustainability aspects in a Gate model for product development

Sustainability requirements and aspects can be integrated in the product development process using a Gate model in the same way as technical, economic and other requirements. A Gate model aims to ensure that product development projects are driven by business objectives and executed with full management commitment in a professional way. The Gate model is made up of stages and gates. "Stages" are periods of activity within a project involving many project team members. To proceed from one stage to the next, a gate must be passed. "Gates" are passed at gate review meetings, where the project team decides whether the predefined Gate criteria have been met. This approach to incorporating sustainability aspects in product development is described based on experience at ABB at the website of the EU-funded DANTES project[250].

ISO/TR 14062 – Integration of environmental considerations in product design and development

The ISO 14000 framework includes the technical report ISO/TR 14062[251], which describes integration of environmental considerations in product design and development. The report sets out concepts and current practice relating to integration of environmental aspects in product design and development. Environmental performance of products can be improved by using ISO/TR 14062.

Other DfE methods and tools

Many DfE methods exist; only a few of them are described here. Apart from integrating environmental considerations in product design in terms of EPIs and into gate model, DfE methods can be used to formulate end-of-life strategies, for example. A DfE method for formulating these strategies across a wide range of products has been developed at Stanford University[252]. The resulting software developed: the "End-of-Life Design Advisor" (ELDA), guides product developers in specifying appropriate end-of-life strategies. These strategies include reuse, service, remanufacture and recycling (with/without disassembly). This method can help

[249] Carlson R, Erlandsson M, Flemström K (2004) *Standards and tools for environmental design and supply chain management in the railway industry,* Industrial Environmental Informatics, Chalmers University of Technology, Sixth International Conference on EcoBalance, Japan.

[250] www.dantes.info, Strategy for R&D, 2005-02-07: http://www.dantes.info/Strategies/R&D/ABBGatemodel/strategies_RandD_ABBGate.html.

[251] International Organisation for Standardisation (2002), ISO/TR 14062: Environmental management - Integration of environmental aspects into product design and development.

[252] Rose C M (2000), *Design for Environment: a method for formulating product end-of-life strategies*, Mechanical engineering and the committee on graduate studies of Stanford University, November 2000; can be found at http://mml.stanford.edu/Research/Papers/2000/2000.dfe.diss.rose/2000.dfe.diss.rose.pdf.

companies to better understand the end-of-life strategy appropriate for their products and to systematically develop tailor-made and profitable end-of-life strategies.

There are many examples of DfE tools on the market: EcoFrontier in Korea has developed a DfE tool called INSTEP-DfE[253]; Toshiba has developed Factor T, which is an eco-efficiency indicator for evaluating functions and environmental aspects of a product[254]. LCA-E[255] is another web-based DfE tool, which enables product developers in the electronics industry to perform environmental screening LCA of printed circuit boards[256].

Applications of the method/tool

DfE methods and tools are often used by professional decision makers such as designers and product developers. Environmental support and marketing functions at companies can also use and benefit from a DfE method. Explicit environmental requirements from customers, e.g. eco-friendliness of the product, are often a criterion given much lower priority than price, quality and function of the product. However, design data in a PDM (Product Data Management) system, for example, can be combined with information on risks posed by materials in products to obtain all necessary details and background information to identify the quantity of hazardous substances in a product.

Compliance with environmental regulations and laws in product design can be achieved by including all relevant regulations and requirements in design projects and translating them into priority design criteria.

DfE methods where environmental and sustainability indicators are interpreted to form design criteria integrated in the design and production process can be used to avoid to introduce environmental problems in product design. The RAVEL method[257] is one example of a DfE method using environmental performance indicators early in the design process to avoid product-related environmental and sustainability problems in the future. If measurable indicators can be defined based on policy and image of a company, they can easily be integrated in product design as design criteria using a DfE method. This makes it possible to ascertain that the policy is being followed.

In addition, DfE results, Safety Data Sheets, success stories, indicator results and relevant product and material data can be used to provide environmentally interested product designers with the right information.

Editor's remarks on applicability of method or tool: The applicability of DfE methods and tools depends very much on the design methods and tools used by a company. Generally speaking, DfE must not be added on top of the designer's workload, but should instead be seamlessly integrated in the work environment. The most beneficial approach is to translate environmental requirements into

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253 Eco-Frontier Co, http://www.ecofrontier.co.kr/eng/business/bus05_03.htm.
254 Toshiba's website for Eco efficiency Factor T: http://www.toshiba.co.jp/env/en/products/factor.htm.
255 About LCA-E: http://extra.ivf.se/lcae/.
256 Erixon M (2001), Information system supporting an web-based screening life cycle assessment tool CPM Report 2001:14.
257 Dewulf, W., Duflou, J., Ander, Å., Integrating Eco-Efficiency in Rail Vehicle Design, Leuven University press, 2001.

design requirements, and to guide the designer on how to avoid improving one dimension at the expense of another. The cost of developing a DfE system may be very high, and must be based on assessments of existing products and customer demands, but use of the methods and tools should be instant and fully integrated. The result may be understood by the designers of the products and by professional procurers of the same products, i.e. by marketing and sales people as well.

3.3.1.3 ENVIRONMENTAL MANAGEMENT SYSTEMS (EMS)

Environmental management systems (EMS) are intended to continuously improve the environmental performance of companies and organisations. The ISO 14001[258] and EMAS[259] standards are widely used in the European Union. Certification under either of the standards assures customers, shareholders and other stakeholders of the company's environmental commitment. Certified EMSs are used in marketing and generate goodwill for the company.

An environmental management system provides with information on the company's environmental performance in terms of emissions, use of resources, noise etc. The EMS also manages information about the significance of environmental aspects and relevant environmental legislation. A method for increased controllability of environmental management systems was developed jointly by industry and experts in a project entitled "Policy controlled environmental management work"[260]. The environmental policy is used as a guiding document for the subjective choices made. The EMS focuses on the site, company or organisation, although information about products is also produced. See the examples in Appendix 1 for more information.

Applications of the method/tool

Under the ISO 14001 standard, the company identifies its environmental aspects and determines which of them has a significant environmental impact[261]. This information is useful for assessing aspects of present or future product life cycles having a potentially adverse effect on the environment. The improved structure of the company's environmental performance, combined with the demand for continuous improvements, will crystallise responsibilities in the organisation.

The information produced by the environmental management system is generally used by management and policy makers at the company to make decisions on investment in environmental improvements, as well as for environmental reporting. EMAS enables companies and organisations to make 'green' claims for marketing purposes[262].

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[258] International Organisation for Standardisation (1997), ISO 14001: Environmental management systems – Specifications with guidance for use.

[259] European Commission (2001), Regulation (EC) No 761/2001 of the European Parliament and of the Council of 19 March 2001 allowing voluntary participation by organisations in a Community eco-management and audit scheme (EMAS).

[260] Carlson R, Häggström S, Pålsson A-C (2004), *Policy controlled environmental management work - Final report*, CPM Report 2004:10, Chalmers University of Technology, Sweden.

[261] International Organisation for Standardisation (1997), ISO 14001: Environmental management systems – Specifications with guidance for use.

[262] KemI (2004), *Information om varors innehåll av farliga kemiska ämnen*, page 91.

Editor's remarks on applicability of method or tool: Environmental management for sustainable development should be defined as described in section 1.2.2, i.e. maintain awareness of the overall sustainability visions, and have a clear view of nearby targets, current status and scope of responsibilities. This is not always the case at present, but the situation may be improved by 1) a better understanding of life cycle responsibilities; and 2) a better understanding of environmental information used for decision making.

3.3.2 Assessment and analysis tools

3.3.2.1 SCENARIO MODELLING

To gain an overview of the life cycles of products it is not enough to describe existing facts, such as the emissions from the upstream processes that produced a specific product, or past environmental impacts due to previous versions of a product. Scenarios must instead be formulated, using knowledge of the past, such as extrapolated current trends, intentional changes, stochastic risks and opportunities, and technical and physical cause-effect relationships.

All methods and tools described in this section are based on the idea of producing these scenarios. Each method or tool describes a technique for choosing the data and knowledge to apply and how to design the cause-effect relationships necessary to achieve specific and well-defined assessment results.

However, it is possible to create many other scenarios using other techniques, slightly or completely different from those described here. A number of relevant scenario models that could substantially aid product life cycle overviews are publicly available scenarios compatibly describing, e.g:

- Regional and local energy systems, infrastructure, population changes, waste management technologies etc. for assessing and improving the environmental performance of products in various markets.
- Future energy systems, infrastructure, population changes, waste management technologies, etc. for assessing and improving the environmental performance of persistent or non-sustainable products.

The emphasis on upstream environmental impacts in life-cycle overviews is sometimes attributed to a lack of available scenario models.

Applications of the method/tool

Scenario modelling is performed by environmental or technical experts. It is often performed in terms of systems analysis. One example of this is a study made at Chalmers University of Technology on environmental assessment of fuel cell systems[263], in which various scenarios were modelled for a specific bus in Gothenburg.

Scenario modelling is used by scientists and environmental experts to measure risk and potential consequences of loss of information, to assess the environmental

[263] Karlström M (2004), *Environmental Assessment of Polymer Electrolyte Membrane Fuel Cell Systems*, PhD study, Chalmers University of Technology.

system consequences of introducing new products for mass consumption, assess the environmental system consequences of redesigning the system, or to appraise future cost increases due to legal, environmental or sustainability aspects of the product. The output information can then be used by company management and other professional decision makers.

Editor's remarks on applicability of method or tool: Substantial expertise is needed to establish well-founded scenario models for future technological and economic development. These are therefore costly, and costs must be shared by public financing or by industrial sectors, for example. Scenarios that are publicly available may make it easier to compare environmental performance assessments.

3.3.2.2 ENVIRONMENTAL RISK ASSESSMENT (ERA)

Risk assessment is commonly defined as the scientific process in which the risks posed by inherent hazards involved in a process or situation are estimated either quantitatively or qualitatively. Risk assessment is a tool used in systems analysis to organise and collate scientific information to help identify existing hazardous situations, anticipate potential problems, establish priorities, and provide a basis for regulatory control and corrective action. It may also be used to help gauge the effectiveness of corrective measures or remedial action[264].

An environmental risk assessment (ERA) is a process of identifying and evaluating the adverse effects on the environment caused by a chemical substance. Environmental exposure to the chemical is predicted and compared with a predicted no-effect concentration, supplying risk ratios for the various media[265]. The predictions are based on properties such as density, toxicity, risk of allergy.

Risk characterisation is an estimation of the severity and incidence of adverse effects likely to occur in a human population or environment. Risk characterisation is divided into hazard assessment and exposure assessment. Hazard assessment consists of hazard identification and a dose response assessment. A hazard (also called effect) assessment is integrated and compared with an exposure assessment to complete a risk characterisation examining whether the Predicted Environmental Concentration (PEC) of a substance released into the environment remains below the Predicted No Effect Concentration (PNEC). A risk characterisation is therefore defined as the ratio between PEC and PNEC[266]. A ratio above 1 represents a risk.

EUSES (the European Union System for the Evaluation of tool of Substances) is one example of a decision-support tool, which makes it possible to assess the general risks a substance poses to man or the environment[267].

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264 Naturvårdsverket (2004), Relationships between Life Cycle Assessment and Risk Assessment – Potentials and Obstacles, Swedish EPA Report 5379.

265 www.dantes.info.

266 ECB (2003), Technical Guidance Document in support of Commission Directive 93/67/EEC on Risk Assessment for new notified substances, Commission Regulation (EC) No 1488/94 on Risk Assessment for existing substances and Directive 98/8/EC of the European Parliament and of the Council concerning the placing of biocidal products on the market, viewed at http://ecb.jrc.it/cgi-bin/reframer.pl?A=ECB&B=/Technical-Guidance-Document/.

267 EUSES can be found at European Chemicals Bureau's (ECB) website: http://ecb.jrc.it/existing-chemicals/.

Applications of the method/tool

Environmental risk assessments can be used to assess the responsibility for ensuring cautious behaviour and to assure the safety of others. System analytical tools or methods may also be needed to perform the whole system assessment. Users of ERA are often environmental or risk specialists or scientists, since detailed knowledge is needed to correctly perform an assessment.

Risk assessment is used to assess factors in the present or intended life cycles of products having a potentially adverse effect on the environment and the health of present and future generations, including allergy and cancer. Scenarios used in risk assessment make it possible to perform streamlined LCA studies and databases on emissions from materials, and to find out whether a product emits hazardous substances at any life cycle stage.

LCA and risk assessment studies can be used to obtain information needed to navigate towards global sustainability in environmental, social, and economic terms. Companies have a responsibility to their shareholders, employees, and lenders to assure economic sustainability, since poor environmental behaviour may have a real adverse impact on the business and its finances. Better economic sustainability is achieved by using system analytical risk assessment and scenario modelling to ensure sustainability of resource consumption, to appraise future cost increases due to sustainability, or to control the environmental impact of the product or production facility.

Finally, data gap analysis and risk assessments can be used to measure risk and potential consequences of loss of information.

Editor's remarks on applicability of method or tool: Substantial expertise is needed to perform an environmental risk assessment of chemical substances. The results cannot be interpreted by laymen without substantial reformatting and translation. The high cost of the studies is justified by the argument that they will help to avoid human and ecological risks.

3.3.2.3 ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

Environmental impact assessment (EIA) is a methodological framework in which impact predictions are examined and reported. EIA is a procedure required under European Union Directives 85/337/EEC and 97/11/EC on assessment of the effects of certain public and private projects on the environment[268]. An EIA is both a tool and a document. An EIA must be performed by anyone applying for a permit to conduct environmentally hazardous activities. The authorities base their permit decisions on the document and it is often also used as a tool to find the optimum design, location, and operation of a project in relation to all components in the environment. An EIA will provide a full view of the possible impacts, and is also site-specific, which allows prediction of the local impact of the project.

EIA highlights the expected effects on the environment before a decision is taken, e.g. before approval of a new production site or other project. Potential effects of the project, such as emissions to air and water, noise, chemicals are

[268] European Commission (2001), *Guidance on EIA – Scoping.*

described, as are the surroundings. This description may be based on direct measurements of local environmental conditions. The environmental impact of the project is compared to a "zero alternative", i.e. the environmental impact on the chosen site if the project is rejected[269]; see Figure 6 below.

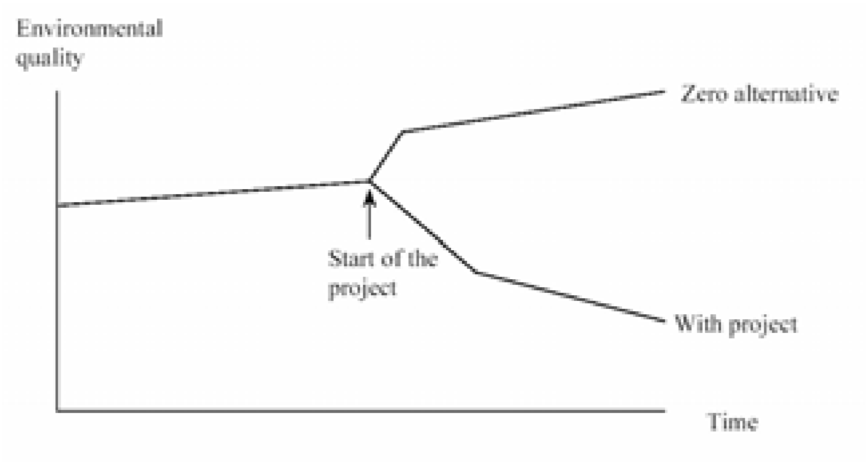

Figure 6. An EIA compares the environmental impact of the project at the site to the zero alternative.

In Sweden there are no explicit requirements as to the environmental issues to be addressed by an EIA. The requirements are those relevant to the project. EIAs therefore vary in quality and appearance[270].

EU Directive 2001/42/EC, which came into force in July 2004, also requires environmental assessments (strategic environmental assessments - SEA) to be performed for certain plans and programmes. An SEA is performed earlier in the process than an EIA so that alternative solutions can be considered before any decisions are taken[271].

Links to environmental impact assessments websites can be found at the Swedish EIA Centre website[272].

Applications of the method/tool

EIA is used by environmental experts to assess factors in the present or intended life cycles of products having a potentially adverse effect on the environment or the health of present and future generations. Since it is a site-specific tool, local, regional, and global effects will be considered.

The information from an EIA is used by the authorities to assess an actor's whole system responsibility, since it is a required document when applying for a permit for environmentally hazardous activities. Examples of EIAs for activities of

269 Industriell miljöteknik (2004), *Kurskompendium i tekniskt miljöskydd*, Linköping University, viewed at http://www.ifm.liu.se/biology/kurser/nbic18/Att%20arbeta%20med%20MKB.pdf.

270 Sandberg F (2004), *Kvalitetsgranskning av MKB - 15 ärenden i Västra Götalands län*. Gothenburg University.

271 Finnveden et al (2003), *Ekonomi, energi och miljö – metoder att analysera samband*, page 16, available at http://www.naturvardsverket.se/dokument/hallbar/miljoeko/samband.pdf.

272 http://www-mkb.slu.se/lankar/lankar.htm.

this kind are storing and handling of petroleum products[273] and electricity generation at a nuclear power plant[274].

Editor's remarks on applicability of method or tool: Substantial expertise is needed to perform an EIA. The results are intended for experts, but can be interpreted by laymen since communication should be part of EIA. The high cost of the studies is justified by the argument that they will help to avoid human and ecological impacts in the long run.

3.3.2.4 LIFE CYCLE ASSESSMENT (LCA)

Life cycle assessment is the assessment of the potential environmental impact of a product or product system at all stages of its life cycle – from abstraction of resources, through the production, transport and use of the product to reuse, recycling or final disposal. LCA methods have been developed as a systematic approach to use of life cycle assessment as a tool[275]. LCA studies may be descriptive, comparative, change-oriented, forecasting, etc. The emphasis of the study will depend on its intended use[276]. See chapter 3.3.3 for a detailed description of LCA.

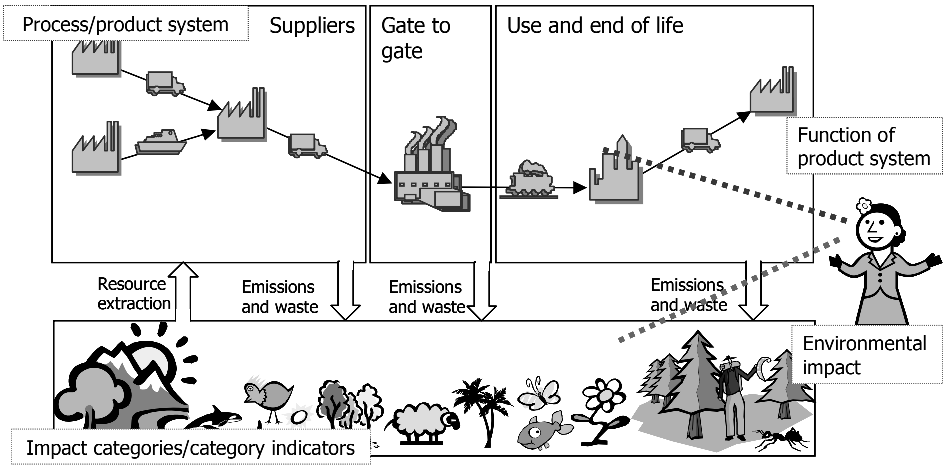

Figure 7. A life cycle assessment includes all stages of a product's life cycle, from cradle to grave. The focus of the LCA study depends on the commissioner and the performer of the study. © Carlson, Pålsson, Chalmers University of Technology, 1998

3.3.2.5 LIFE-CYCLE COST (LCC)

Life-Cycle Cost (LCC) is a tool used to calculate the economic costs caused by a product or a service during its entire life cycle, from purchase of raw materials and components, cost of production and investments to use, maintenance, and waste management. LCC calculations may include initial costs (purchase price), installation and operation costs, maintenance costs, energy costs and environmental costs. Environmental costs are calculated by assigning a monetary value to the

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[273] Länsstyrelsen i Stockholms län, *SÖDERTÄLJE KOMMUN –ansökan och miljökonsekvensbeskrivning*, published in Dagens Nyheter 13[t] August 2003.

[274] Barkefors, Hydén (2005*), Miljökonsekvensbeskrivning (MKB) för Forsmarks Kärnkraftsverk - förslag till disposition*, Forsmarks kraftgrupp.

[275] Erixon M (1999), Practical Strategies for Acquiring Life Cycle Inventory Data in the Electronics Industry, CPM Report 1999:3.

[276] Carlson R, Häggström S, Pålsson A-C (2003), *LCA course for users of LCA data and results*, Report for the CASCADE Project, available at http://192.107.71.126/cascade/.

environmental impacts. These can be internalised as a cost for the organisation causing the impact, as with costs for anticipated climate change in the European Emissions Trading Scheme[277]. External costs for environmental impacts may be assessed using a cost-based weighting[278].

At present there are no standardised guidelines as to which costs to include in an LCC study. Costs include direct and indirect external costs, depending on the description or definition of the method used. The life cycle used in the method is the economic life cycle of the system. This may be the time from development, purchase, use, and end of life, but may also be the economic life during use alone[279].

Applications of the method/tool
LCC is a tool for scientists and experts producing information for professional decision makers and consumers. It can be used with LCA studies and scientific analysis of mechanisms to internalise external costs. One attempt to do this is described in the report "External Environmental Costs in LCC" by B. Steen[280].

Editor's remarks on applicability of method or tool: Both LCA and LCC are costly and are mainly intended for experts, unless the result is substantially reformatted and translated into the language of the audience.

3.3.3 Life cycle assessment (LCA)

Our terms of reference specifically include an additional exposition on LCA methodology. LCA assesses the environmental impact of a product life cycle. The objectives and scope of the study are set to make the task feasible. A life-cycle inventory (LCI) of the examined product is performed. This includes modelling the life cycle as processes, including transport, and documenting the inputs and outputs for the processes. The environmental impact of the inventory results is assessed using characterisation models to form a life-cycle impact assessment (LCIA) profile. The characterisation model describes the impact of inputs and outputs on category indicators, i.e. indicators of the environmental conditions of concern. Examples of category indicators include biodiversity, ozone depletion, etc. A subjective weighting between category indicators can be performed to allow comparison between environmental impacts and to provide a single measure of the product's environmental performance. The category indicators are given weighting factors reflecting the concern about the various environmental impacts. The results of the study are compared with the objectives and scope, interpreted and communicated.

Life-cycle assessment applications range from quick screening analyses, which are used to identify potentially important issues ("hot spots") for further study and

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277 European Commission (2005), EU Emissions Trading. An open scheme promoting global innovation to combat climate change.

278 Steen B (1999), A systematic approach to environmental priority strategies in product development (EPS). Version 2000 – Models and data of the default method, CPM report 1999:5, Chalmers University of Technology, Sweden.

279 Finnveden et al (2003), *Ekonomi, energi och miljö – metoder att analysera samband*, available at http://www.naturvardsverket.se/dokument/hallbar/miljoeko/samband.pdf.

280 Steen B (2003), *External environmental costs in LCC*, Chalmers University of Technology, viewed at http://www.dantes.info/Publications/.

to help audiences "see" or "map" a system whose issues might be concealed or hard to understand, to rigorous and detailed studies, which are intended to provide authoritative information for a public decision. The requirements of these and many other applications vary significantly. Defining the goal and scope involves determining the appropriate degree of rigour for each of the elements, given the intended use of the study and the resources available, in terms of time and money[281].

3.3.3.1 STANDARDS

ISO standards
LCA methodology has been standardised by the International Organisation for Standardisation (ISO). The ISO 14040 standard[282], divides an LCA into four phases:

- Goal and scope definition
- Inventory analysis
- Life cycle impact assessment
- Life cycle interpretation

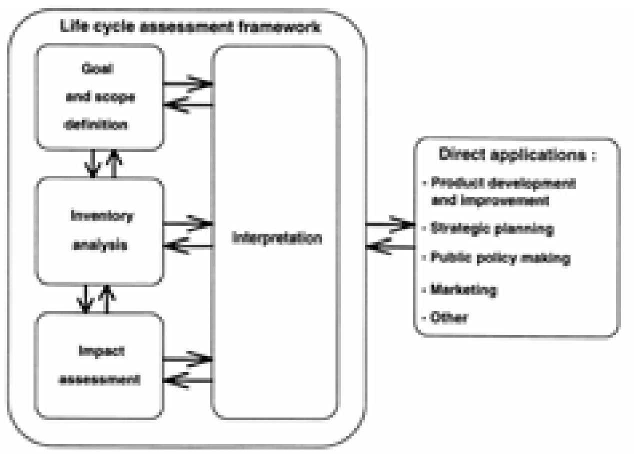

Figure 8. The framework of life cycle studies according to ISO 14040. © ISO 1997.

The procedures are described in ISO 14041[283], ISO 14042[284] and ISO 14043[285]. The ISO standardised procedure for LCA is sometimes referred to as "traditional", "conventional"[286], "full" or "complete" LCA[287].

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281 Todd J A, Curran M A (1999), Streamlined Life-Cycle Assessment: A Final Report from the SETAC North America Streamlined LCA Workgroup, SETAC.
282 International Organisation for Standardisation (1997), ISO 14040: Environmental management - Life cycle assessment - Principles and framework.
283 International Organisation for Standardisation (1998), ISO 14041: Environmental management - Life cycle assessment - Goal and scope definition and inventory analysis.
284 International Organisation for Standardisation (2000), ISO 14042: Environmental management - Life cycle assessment – Life cycle impact assessment.
285 International Organisation for Standardisation (2000), ISO 14043: Environmental management - Life cycle assessment – Life cycle interpretation.
286 Erixon M (1999), Practical Strategies for Acquiring Life Cycle Inventory Data in the Electronics Industry, CPM Report 1999:3.
287 http://www.dantes.info/Strategies/EnviroSupp/LCA/strategies_LCA.html.

The ISO/TS 14048 technical specification[288] describes a data documentation format for life cycle inventory data compatible with the ISO 14040 series of standards. The data documentation format facilitates compliance with the requirements of the other standards in the series, as well as interpretation and communication of data.

More information on how to perform an LCA is given in Appendix 1.

3.3.3.2 SYSTEMATIC

Streamlined

The SETAC Europe Working Group defines simplified LCA and streamlined LCA as synonymous[289] and the concepts are therefore treated as such here. The SETAC North America Streamlined LCA Working Group defines Streamlined LCA as: Identification of elements of an LCA that can be omitted or where surrogate or generic data can be used without significantly affecting the accuracy of the results. Concerns about the cost and time required for LCA have encouraged some practitioners to examine the possibility of "streamlining" LCA. There has been a growing recognition that "full-scale" LCA and "streamlined" LCA are not two separate approaches but rather points on a continuum. Most LCA studies will fall somewhere along that continuum, in between the two extremes. As a result, the process of streamlining can be viewed as an inherent element of the goal and scope definition process[290].

In a simplified LCA, compared with a screening LCA, less cautious assumptions are made concerning the cut-offs, based on what is considered to be of importance for the purpose of the LCA. A simplified LCA therefore only takes a few weeks[291].

Based on national statistics

An Input-Output analysis (IOA) summarises all necessary inputs and all resulting outputs to make a given product and can thus be used to find the cradle-to-gate environmental impact of the product. Input-Output analyses are an analytical application of the environmental and economic accounts assembled by the national statistical authorities of most countries. The statistics, and thus the environmental assessment, are based on product group data, not actual data for a specific product. It is further assumed that the relationship between economic activity and environmental impact is linear[292].

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[288] International Organisation for Standardisation (2002), ISO/TS 14048: Environmental management - Life cycle assessment – Data documentation format.

[289] Tasaki T, Moriguchi Y (2004), *Review and Categorisation of Simplified/Streamlined Assessment Methods,* National Institute for Environmental Studies, Japan.

[290] Todd J A, Curran M A (1999), Streamlined Life-Cycle Assessment: A Final Report from the SETAC North America Streamlined LCA Workgroup, SETAC.

[291] Erixon M (1999), Practical Strategies for Acquiring Life Cycle Inventory Data in the Electronics Industry, CPM Report 1999:3.

[292] Finnveden et al (2003), *Ekonomi, energi och miljö – metoder att analysera samband*, page 16, available at http://www.naturvardsverket.se/dokument/hallbar/miljoeko/samband.pdf.

IOAs differ from LCAs in that they do not include the impact of the use or disposal of the product and are based on national statistics. Sometimes geographical borders are system boundaries, e.g. the material or energy chain is severed at the national border[293].

More information about IOA is given in an example in Appendix 1.

Key system indicators

The life-cycle impact of a product is modelled in LCA by selecting a set of indicators, called "category indicators"[294]. The term category indicator has the same meaning in LCA as the environmental performance indicators (EPIs) in the ISO 14031 standard[295]. The indicator set has the role of spanning the full relevant and significant environmental impact domain of the product, and enabling a quantitative evaluation of its performance[296].

There are two ways of performing a life cycle assessment based on indicators. The first is to summarise the life cycles of the materials included, raw material abstraction and production together with probable future use and disposal scenarios as is done using the EPS method[297]. The indicators are aggregated measures of the life cycle environmental impact, e.g. "crop production capacity", "drinking water", "morbidity", etc.

The second way is to let the indicator define one environmental dimension of a subject of study, e.g. the degree of recyclability of an electric motor, the number of tonnes of carbon dioxide emitted by a factory, or the increase in the number of cancer cases among human populations due to environmental causes. One subject of study, such as a motor, a factory or a full supply chain, from raw material abstraction to market, is generally described by a set of many indicators[298]. This method was developed and implemented in the RAVEL and REPID projects[299] and it introduced Design for Environment in the railway industry (see 3.3.1.2). Various material properties are stored in the REPID database, which can be used to calculate indicators on the environmental performance of the product, e.g. "fraction recycled materials", "can be incinerated with energy recovery", "amount of potentially hazardous waste"[300]. The choice of indicators or, indirectly, material properties, when designing the material database, is equivalent to the scoping in an LCA study.

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[293] Naturvårdsverket (2002), *Kunskap om produkters miljöpåverkan: vad ger dagens statistik?*, Swedish EPA Report 5231.
[294] International Organisation for Standardisation (2000), ISO 14042: Environmental management - Life cycle assessment - Life cycle impact assessment.
[295] International Organisation for Standardisation (1999), ISO 14031: Environmental management - Environmental performance evaluation – Guidelines.
[296] Carlson Raul (2002), *Environmental Performance Indicators*, Published in INSIGHT, Vol 5 Issue 2 July 2002 p. 22-23, The International Council on Systems Engineering (INCOSE).
[297] Steen B (1999), A systematic approach to environmental priority strategies in product development (EPS). Version 2000 – General system characteristics, CPM report 1999:4, Chalmers University of Technology, Sweden.
[298] Carlson Raul (2002), *Environmental Performance Indicators*, Published in INSIGHT, Vol 5 Issue 2 July 2002 p. 22-23, The International Council on Systems Engineering (INCOSE).
[299] http://www.railway-procurement.org/.
[300] Flemström K (2003), *Environmental Performance Indicator (EPI), Methodology in REPID*, Chalmers University of Technology, Sweden.

Systematised LCA

Environmental product declarations (EPD) are used for systematised communication of environmental product information based on LCA/LCI data. EPD methodology is described in ISO 14025[301] (see also section 3.2.3.1). The exact type of information is specific to a particular type of product group and is determined in "product-specific requirements" (PSR). These are drawn up by industry in close consultation with stakeholders and competitors. PSRs do not contain limit values, although they can contain thresholds below which the presence of certain LCA data does not have to be declared, since it is not cost-effective to collect. The information is then presented in a common format and in a neutral way allowing evaluations and comparisons by the purchaser but it does not seek to judge the environmental characteristics of a product. The quality of the information is then verified by a third party and can be accredited if considered necessary to add credibility[302].

The drawback of systematised LCA studies such as EPD is that the results can easy be perceived as "true", since information about the selections made to create the system is seldom presented together.

3.3.3.3 OVERVIEWS

Screening

The SETAC North America Streamlined LCA Workgroup defines Screening LCA as: "an application of LCA used primarily to determine whether additional study is needed and where that study should focus"[303]. This view is shared with PRé Consultants, which says that 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[304].

The DANTES project views screening LCA as a study conducted with a lower degree of detail than complete LCIs[305].

A report about LCIs in the electronics industry states that a screening LCA adopts a holistic approach to the system, but using easily accessible data. A well-documented screening LCA takes a few weeks to complete[306].

The views differ mainly regarding the application of the screening LCA, and screening LCA can therefore be seen as an LCA that covers the whole life cycle but has a low level of detail.

Matrix LCA

Matrix LCA is a qualitative or semi-quantitative assessment. In this method, several items are simultaneously evaluated in the form of matrices[307].

[301] International Organisation for Standardisation (2002), ISO 14025: Environmental labels and declarations - Type III environmental declarations.
[302] European Commission (2001), Environmental Product Declarations (ISO 14025 Technical Report).
[303] Todd J A, Curran M A (1999), Streamlined Life-Cycle Assessment: A Final Report from the SETAC North America Streamlined LCA Workgroup, SETAC.
[304] PRé Consultants, http://www.pre.nl/life_cycle_assessment/life_cycle_assessment.htm.
[305] http://www.dantes.info/Strategies/EnviroSupp/LCA/strategies_LCA.html.
[306] Erixon M (1999), Practical Strategies for Acquiring Life Cycle Inventory Data in the Electronics Industry, CPM Report 1999:3.
[307] Tasaki T, Moriguchi Y (2004), *Review and Categorisation of Simplified/Streamlined Assessment Methods,* National Institute for Environmental Studies, Japan.

Matrix LCA is a quick, qualitative method of ascertaining the environmental impact of a product life cycle. The matrices take account of all the life-cycle phases and include consumed energy and material and toxic emissions from those phases[308]. Some examples of simplified LCA matrices are the MET matrix[309] and the MECO matrix[310]. A qualitative matrix LCA only takes a few hours to make[311].

3.3.3.4 BENEFITS AND DRAWBACKS

The proper type of LCA to use depends on the purpose of the study and the resources available. The time expended is often pointed out as the major drawback of LCA[312]. In the report "*Practical Strategies for Acquiring Life Cycle Inventory Data in the Electronics Industry"* by Maria Erixon, LCA experts are interviewed about the time involved in an LCA study. A summary of their views is that it takes between 5 minutes and two years to perform an LFA and costs between €10,000 and €200,000. When interviewed, the experts referred to various kinds of life cycle assessment, and not all of them included data acquisition in their estimate. Thus, the "five-minute" LCA assumes the necessary LCI data is readily available. The interviews also show that data acquisition is one of the most time-consuming, and thus most costly, parts of an LCA[313].

Generally, the more specialised the scope and the more simplifications made, the less reusable the data are for other studies.

LCA studies often focus on the upstream impacts of a product. This may be due to a lack of models for use scenarios and data about the use and disposal phases. The upstream focus may also be an inherent feature of the tool, as with EPD, where the chosen product-specific requirements mainly describe upstream activities, and with I/O analysis, which is a method for cradle-to-gate assessments of products.

The upstream focus may also be due to the scope of the study. The scope is set by those commissioning the work - often a customer requiring information on the environmental performance of a product before buying it. He might not be interested in an analysis of the way his own use of the product impacts the environment.

3.3.3.5 APPLICATIONS OF THE METHOD/TOOL

LCA studies are performed by environmental experts. The variants described above make LCA a tool that can be used for numerous purposes. A few examples are given below. The results of an LCA study are compiled in a report largely intended for other environmental experts. However, since the principle of LCA is

[308] Widheden J (2002), Methods for environmental assessment – useful to the DANTES project, Report for the DANTES project.
[309] Norrblom H L, Jönbrink A K, Dahlström H (2000), *Ekodesign – praktisk vägledning*, Institutet för Verkstadsteknisk Forskning, Sweden.
[310] Pommer K, Bech P, Wenzel H, Caspersen N, Olsen S I (2001), *Håndbog i miljøvurdering af produkter -en enkel metode*; Miljønyt Nr. 58 2001, Miljøstyrelsen, Miljø og Energiministeriet, Denmark.
[311] Erixon M (1999), Practical Strategies for Acquiring Life Cycle Inventory Data in the Electronics Industry, CPM Report 1999:3.
[312] Todd J A, Curran M A (1999), Streamlined Life-Cycle Assessment: A Final Report from the SETAC North America Streamlined LCA Workgroup, SETAC.
[313] Erixon M (1999), Practical Strategies for Acquiring Life Cycle Inventory Data in the Electronics Industry, CPM Report 1999:3.

quite easy to understand, interpretations of the results can be understood by people with little or no environmental knowledge. This can be done by communicating them in an understandable form, e.g. an environmental product declaration, or by aggregating them into a key indicator value.

Life-cycle inventory
In practice, the inventory of carbon dioxide emissions being performed under the emissions trading scheme[314] is a streamlined gate-to-gate LCA: the scope is confined to examining greenhouse gases alone, and there is no impact assessment.

The inventory part of LCA studies may involve a detailed study of the materials included in a product. The presence of scarce materials in the product can be examined and matched with other information about scarce material (e.g. in the impact assessment method, where "depletion of scarce resources" is a common impact category[315]). LCA can be used to ascertain whether a product emits hazardous substances at any stage of its life cycle. One example is the study by the US EPA comparing liquid crystal displays (LCD) and cathode ray tube (CRT) technologies. Larger quantities of mercury were used in the CRT life cycle than in the LCD life cycle, even though only LCD displays actually contain mercury. The greater amount of mercury is from the release of mercury and mercury compounds from electricity generation. Since the CRT life cycle uses more electricity than the LCD, more mercury was released by CRT displays than LCDs[316].

Systems analysis
LCA can be used for systems analysis, e.g. assessment of environmental system consequences of introducing new products for mass consumption. The impact on the environment of small-scale use of products is often negligible, but must nonetheless be taken into account in scenarios for large-scale use when introducing new products and product systems[317].

The ability to adopt a systems perspective makes LCA a useful tool for assessing the environmental system consequences of redesigning the system. LCA can then be used to compare various home heating options, for example, such as district heating, heating oil and direct electric heating[318].

LCA can also be used to assess the environmental system consequences of individual life-style choices. An LCA study has shown that travelling by train instead of car or plane may have less environmental impact, particularly if the electricity generated to run an electrified railway line comes from renewable resources[319].

When comparing waste management options for specific products or materials it is often essential to examine the system consequences. An LCA study by T.

314 http://europa.eu.int/comm/environment/climat/emission.htm.
315 Utrecht University (1993) *"Environmental LCA of four types of floor covering"*, Utrecht University Department of Science, Technology and Society, Netherlands.
316 Socolof M et al (2001), *Desktop Computer Displays: A Life Cycle Assessment*, EPA-744-R-01-004a, http://www.epa.gov/dfe/pubs/comp-dic/lca/index.htm.
317 Frankl P, Masini A, Gamberale M, Toccaceli D, *Simplified LCA of PV Systems in Buildings: present situation and future trends*, Center for the Management of Environmental Resources (CMER), INSEAD.
318 http://www.vattenfall.se/om_vattenfall/var_verksamhet/var_produktion/livscykelanalyser/.
319 http://www.om.sj.se/.

Ekvall and J. Sahlin at Chalmers University of Technology has shown that energy recovery of a material by incineration often replaces other waste incineration due to limitations in incinerator capacity, with the result that other waste flows are deposited at landfills[320].

Assessment of consequences
LCA studies examine the potential environmental impacts of product life cycles, now and in the future. LCA is a good way of ascertaining the environmental consequences of the use of products. Life-cycle assessments are produced globally and in all kinds of areas: food[321], electronics[322], buildings[323], etc.

The monetary cost of the environmental burden can be determined by an LCA study so that it can be internalised in the product price (see 2.1.4.2). The EPS method uses the willingness to pay (WTP) to remedy impacts on "safeguard objects", as measured amongst OECD inhabitants[324]. The life-cycle cost of a product can be determined using life-cycle assessment methods for models of fuel tax, disposal cost or increased price of scarce materials (see LCC).

An LCA study can help determine future costs due to sustainability or environment aspects of product. The availability of platinum is a key issue for fuel cell vehicles. The volatile price of the metal may cause difficulties for fuel cell vehicle developers, as there is currently no feasible alternative to platinum as a catalyst in fuel cells for transport applications, except perhaps palladium, which offers little advantage in terms of cost or availability[325].

LCA can be used to ensure that products designed to improve the environment do not cause environmental damage at other stages of their life cycle. One example is a comparative LCA study of glass bottles and one-way PET bottles. Glass bottles were assumed to be more environmentally friendly, since they are used several times, require fewer resources and generate less refuse. However, glass bottles consume water and energy when washed and reconditioned, and they are much heavier than PET bottles, thus increasing fuel consumption for transport. The LCA study concluded that the environmental impact of PET bottles was equal to that of glass bottles[326].

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320 Ekvall T, Sahlin J (2001), *Swedish waste incineration and electricity production*, Proceedings from Workshop on System Studies of Integrated Solid Waste Management in Stockholm 2 - 3 April 2001.

321 Berlin J (2002), Environmental life cycle assessment (LCA) of Swedish semi-hard cheese, International Dairy Journal. 12(11), 939-953.

322 Bang and Olufsen (1997), *LCA of a television – the Beovision LX 5500*, Published in Environmental Assessment of Products – volume I – methodology, tools and case studies in product development. ISBN 0 412 80800 5, 1997.

323 Widman J, Eklund L-J (2004), *Life-cycle Assessment of Steel Construction*, SBI Report 213:1.

324 Steen B (1999), A systematic approach to environmental priority strategies in product development (EPS). Version 2000 – Models and data of the default method, CPM report 1999:5, Chalmers University of Technology, Sweden.

325 AEA Technology (2003), Platinum and hydrogen for fuel cell vehicles, AEA technology, Harwell, UK.

326 Petcore (2004*),"World largest PET Life Cycle Assessment - One-way PET levels with refillable glass*, IFEU Heidelberg, Germany and http://www.insead.edu/CMER/research/econ/bottlewars.htm.

Informative
LCA can be used to examine responsibility for the environmental impact of a product. Extended Producer Responsibility[327] is based on knowledge of the entire life cycle and modelling probable scenarios for use and disposal.

LCA can provide the information needed to act and think responsibly within a responsible culture. The information communicated to people to try to change their habits is often based on LCA and is simplified so that ordinary people can understand it. The European Association of Consumer Cooperatives says that providing consumers with full information is the best way to make them genuine actors and that eco-labels, for example, do not give them enough information to make a choice [328].

LCA studies can help find the phases of a product's life on which a given stakeholder can have an impact, clarify how much of a product's impact is known and provide information about possible future costs.

3.3.3.6 LCA & LCC
Life-cycle cost (LCC) analysis is an economic analysis technique that allows comparison of investment options. An LCC includes the costs and time associated with each option over a selected analysis period and converts those costs into economically comparable values[329].

LCA and LCC studies generally have different system limits, in which case comparison between results is not recommended.

3.3.3.7 TOOLS, SYSTEMS AND SOFTWARE
There are a number of commercial LCA tools[330]: GaBi, SimaPro, and LCAiT to mention a few. The DANTES website provides a free, simple web-based LCA tool called LCALight[331]. The LCI Questionnaire, also available at the DANTES website, can be used to gather information from suppliers[332].

A screening LCA tool was developed for the electronics industry in a project called "Strategy for Life Cycle Assessment in the Electronics Industry - Inventory" (LCAE). The project was developed jointly in 2001 by the Centre for environmental assessment of Product and Material systems (CPM) at Chalmers University of Technology and IVF[333].

3.3.3.8 *EDITOR'S REMARKS ON APPLICABILITY OF LCA*
Although LCA is very easy to understand, most ways of performing an LCA are either costly or questionable; it is costly to acquire the data needed but any simplifications made are often difficult to justify. As yet there is no consensus on these

327 Environment Canada, http://www.ec.gc.ca/epr/en/epr.cfm.
328 http://www.eurocoop.org/publications/en/memos/memo96.asp.
329 Ravemark Dag (2003), *State of the art study of LCA and LCC tools*, Report for the DANTES project accessible at http://www.dantes.info/Publications/publications.html.
330 www.life-cycle.org.
331 http://www.dantes.info/Sustanabillitytools/Software/webbasedtools_LCALight.html.
332 http://www.dantes.info/Strategies/EnviroSupp/LCA/strategies_LCA_work_doc.html.
333 Erixon M (2001), Information system supporting a web-based screening life cycle assessment tool CPM Report 2001:14.

simplifications, because they are based on various ad hoc assumptions about the world or about simplified data. Justifying the rectitude of the simplification choices may be as costly as better data. The fact that LCA produces results that are the subject of debate suggest that it is an expert tool. Parts of an LCA may be understood by professionals and laymen alike, but those parts should be translated using various methods and tools as described in sections 3.2.1 and 3.2.2, for example.

3.4 Support tools

There are many types of support tool. In this section "support tools" have been divided into databases, data gap analysis, market analysis, material inventory methods and tools and data input methods and tools.

3.4.1 Databases

A database is a collection of information organised so that it can be easily accessed, managed and updated. Database software thus helps to manage any information needed for environmental analysis. Many product databases can be found at companies, public authorities and organisations, e.g. the substance classification lists and restricted substance database at the Swedish Chemical Inspectorate (KemI) website, databases containing economic values for tasks and materials and also scenario databases.

3.4.1.1 MATERIAL LISTS

Product content can be saved in material lists or inventory databases, e.g. the automobile industry's IMDS (International Material Data System)[334] which contains a material database and a supply chain tool enabling suppliers to declare the materials used in their products. Material lists can also be used to specify materials whose use is forbidden or restricted at a company or organisation.

3.4.1.2 CLASSIFICATION LISTS

KemI has several substance databases, e.g. the Classification List, which contains binding health and/or environmental classifications (risk phrases) for over 2,900 substances, isomers, closely-related substances and other substance categories.

3.4.1.3 RESTRICTED AND PROHIBITED SUBSTANCE LISTS

KemI has a substance database specifying whether a substance or group of substances is restricted or banned according to European and Swedish legislation [335]. This database is named "Restricted Substance Database".

3.4.1.4 APPLICATIONS OF THE METHODS/TOOLS

Databases such as material lists, classification list, technical systems, etc.can generally be used by various user categories, e.g. professional decision makers

[334] EDS, http://www.mdsystem.com/html/en/home_en.htm.
[335] KemI, www.kemi.se, see KemI's restricted database at: http://www.kemi.se/_app/begransningsdatabas/default.cfm.

(designers, purchasers, etc) and also environmental experts, policy makers and authorities.

Data sets such as material lists can serve as a tool when performing a material inventory of a product. Common material nomenclatures are defined in databases and the user performing the inventory can find a specific material in the database. Material lists may also be useful for identifying hazardous substances in a product or assessing whether a product contains scarce substances. As a complement, it is essential to have access to databases or other sources of information on scarcity and toxicity of materials.

Material lists can also be used with other information such as toxicity data, scenario modelling data, economic values for tasks and materials, databases of information on emissions from materials to obtain all necessary details and background information to place an economic value on the material content of waste fractions and to assess whether a product emits hazardous substances at any stage of its life cycle.

Lists of restricted and prohibited substances are often used by companies, e.g. Volvo Car Corporation[336], ABB[337]. These lists are used by designers to help them choose materials with less environmental impact and also in purchasing and communication with suppliers.

Risk identification or self-classification using the international risk phrases in KemI's classification list is performed by several companies.[338] Two types of risk phrase are used: "single risk phrases" (e.g. R20 – Harmful by inhalation), and "combined risk phrases" (e.g. R 20/21– Harmful by inhalation and in contact with skin).

Databases specifying the economic value of materials can be used by professional decision makers, for example, to value the material content of a waste fraction. LCC, material lists and economic recycling value may be useful when placing an economic value on long-life products based on material content. Weighting methods such as the EPS method are also used in LCA studies.

Databases containing various scenarios can be used with data for Environmental Risk Assessment (ERA) and Safety Data Sheets (SDS), material databases, economic value of materials and data on materials as a resource to determine the quantity of hazardous substances in a product and how to handle them, to place an economic value on the material content of a waste fraction and to assess whether a product emits hazardous substances at any stage of its life cycle.

Databases with inventories of technical systems (LCIs) are useful when performing LCA studies. A technical system sufficiently documented in one LCA study will not need to be documented again for a second study, but the dataset can

[336] Volvo Cars' restricted list can be found at: http://www.id.volvocars.com/FinancialServices/PlansPrograms/EnvironmentalFirsts.htm.

[337] ABB's website: http://www.abb.com/global/abbzh/abbzh251.nsf!OpenDatabase&db=/global/seitp/seitp255.nsf&v=499A&e=us&c=D5210C4E1F10E6C1C1256C6A004870FC.

[338] Naturvårdsverket (2004), Relationships between Life Cycle Assessment and Risk Assessment – Potentials and Obstacles, Swedish EPA Report 5379.

be reused. Datasets with documentation of technical systems from the SPINE@CPM database were used in an LCA study by SKF Sverige AB[339].

Editor's remarks on applicability of method or tool: Establishing material databases of components, products and production is costly, but costs may be shared with others in the same sector, for example. It is expensive to establish databases because different materials and material properties are relevant for different products, data must be based on lower-level primary data, which might be hard to find, and expert knowledge is needed. Depending on the purpose of the database, it may be interpreted by experts, professionals or laymen.

3.4.1.5 ECONOMIC VALUE

3.4.1.5.1 Economic value of materials and substances

The economic value of materials and substances can be found in various databases, e.g. costs of recycled or virgin metals and other construction materials. Futures prices are shown on the London Metal Exchange and New York Mercantile Exchange websites, which provide up-to-the-minute information on metal futures and options contracts, and also general information about the market[340]. Apart from current price quotes and charts, the sites provide historical price data, etc[341]. *Metal Bulletin* provides its subscribers with twice-weekly reports on a wide range of ferrous and non-ferrous metals, including current prices[342].

Models incorporating the economic value of materials and substances have been developed. One is the Valuation of Recycled Material (VARM) model, developed by a master's thesis student at Chalmers University of Technology in 2000. The model combines a material pool concept with an economic allocation procedure. The economic allocation follows price trends in the commodities market. The VARM model is suitable for materials for which there is a well-established second-hand market, e.g. aluminium[343].

The Environmental Priority Strategies (EPS) method includes abiotic stock reserves such as fossil oil, bauxite, bromide and sodium, human health and ecosystem production capacity, e.g. crops, timber, fish, and meat[344, 345]. Economic values for these areas has been measured or estimated for use in the impact assessment part of LCA studies, for example.

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339 Häggström S, Berg H (2002), *LCA based solution selection*, Department of Chemical Environmental Science, Chalmers University of Technology.

340 London Metal Exchange, http://www.lme.co.uk.

341 New York Mercantile Exchange, http://www.nymex.com.

342 Metal Bulletin, http://www.metalbulletin.com.

343 Strömberg K, (2000) Valuation of Aluminium in Recycling Systems – A method development – Modelling- Software development, Chalmers University of Technology, Sweden.

344 Steen B (1999), A systematic approach to environmental priority strategies in product development (EPS). Version 2000 – General system characteristics, CPM report Chalmers University of Technology Sweden.

345 Steen B (1999), A systematic approach to environmental priority strategies in product development (EPS). Version 2000 – Models and data of the default method, CPM report Chalmers University of Technology Sweden.

3.4.1.6 SCENARIOS

Databases containing models describing scenarios could be useful for modelling the environmental impacts of long-life products, infrastructure changes or waste management, but databases of this kind are yet to be established.

3.4.1.7 TECHNICAL SYSTEMS

Data about technical systems such as industrial processes can be found in Life-Cycle Inventory (LCI) databases, e.g. LCI@CPM[346], EcoInvent[347], and JEMAI[348].

LCI data describes environmentally relevant inputs and outputs of a defined model of a technical system (see Figure 9)[349]. The inputs and outputs consist of energy and matter used in the technical system to perform a well-defined function, expressed by a functional unit. For example, the technical system may be a production facility for the manufacture of polyethylene. The function of the system may thus be defined as "production of polyethylene", and the functional unit as 1 kg polyethylene. Examples of relevant inputs and outputs are natural resources, raw materials, "energy ware", ancillary materials, products, by-products, emissions to air, water and soil, residues etc. The data documentation format for LCA, ISO/TS 14048, refers to a model of a technical system as a Process, and the inputs and outputs in the process are termed inputs and outputs.

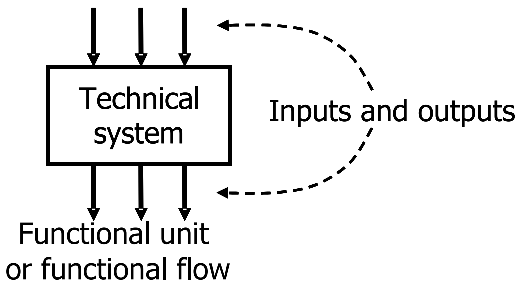

Figure 9. Model of a technical system[350].

A model of a technical system may have an inner structure, i.e. be composed of models of technical systems, e.g. as a combination of unit processes (see Figure 10). For example, in an LCA study, a flow model of the product system is obtained by linking models of smaller technical systems together in a flow chart. The models are linked to each other by their inputs and outputs. Other types of flow model may also be designed and used in LCA. For example, a model of a production line at a site may comprise models of the process steps included. In addition to flow chart models, the models with an inner structure may consist of a number of similar models of technical systems forming an average, for example an industrial average

346 LCA@CPM, http://kakapo.imi.chalmers.se/nukes/index.html.
347 EcoInvent, http://www.ecoinvent.ch.
348 JEMAI, http://www.jemai.or.jp/english/index.cfm.
349 Pålsson A-C.; "Introduction and guide to LCA data documentation using the CPM data documentation criteria and the SPINE format"; CPM Report 1999:1.
350 Pålsson A-C.; "Introduction and guide to LCA data documentation using the CPM data documentation criteria and the SPINE format"; CPM Report 1999:1.

for a specific product, based on information about the various production sites included in the average.

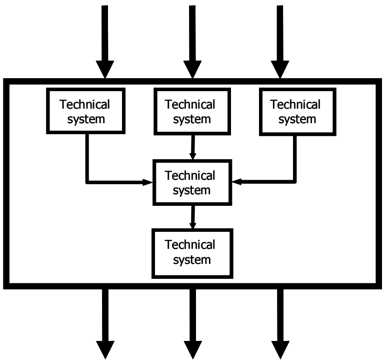

Figure 10. Model of a technical system composed of models of technical systems.

Models of technical systems are acquired by modelling a real technical system. A model is generally acquired for a given application and purpose. During the modelling process many subjective choices are made, which the modeller and data user need to be aware of, since all of these choices have a major influence on the result, e.g. choices as to the inputs and outputs considered environmentally relevant and that should therefore be included, the chosen quantitative reference, what is included and what is excluded in the model, which data sources are used, etc. All choices made during modelling of the technical system must be sufficiently documented so that others are able to interpret and understand the model[351].

Editor's remarks on applicability of method or tool: Databases specifying the economic value of materials and scenarios of market and societal trends are a great help when making decisions on product design and material choices, but they are costly to establish, and they require substantial expertise. It is highly recommended that databases of this kind be established in industrial sectors or by public funding. They may be used for many sustainability decisions throughout the global community. Databases describing the environmental behaviour of technical systems may be developed by companies, industrial research institutes, specialised engineering teams and academic institutions, for use in education, for modelling and as modules for LCA studies. Establishing all these types of database requires a great deal of expertise if they are to be suitable for use by experts. But if the databases are made available to the public, the results may become more easily understandable and gain credibility.

3.4.2 Data gap analysis

Sets of environmental data often contain data gaps. Data gap analysis can be used to identify missing information and to ascertain the consequences of its absence. Transparent documentation is needed to determine whether required data is based

[351] Flemström K, Pålsson A-C (2003), Introduction and guide to LCA data documentation using the CPM documentation criteria and the ISO/TS 14048 data documentation format, CPM report 2003:3.

on measured observations or on assumptions. A sensitivity analysis can be used to examine the impact of data gaps.

The method of managing data gaps will impact the result achieved by the tool using the data. How data gaps have been managed is therefore useful information. According to the Swedish Chemicals Inspectorate, the best way to prevent data gaps is legal regulation[352].

It can be very instructive to know why the data is missing. Gaps may

- exist randomly
- result from the wrong collection method
- be due to carelessness, negligence or the ignorance of the sampler
- be inherent in the property/object examined
- exist because the information has not been requested.

The reasons why data is missing may also be unknown. With environmental information it is very common that information about a property or an object has never been requested and therefore not observed[353].

Applications of the method/tool

Data gap analysis can be used by experts to measure risk and potential consequences of information loss. One example of the use of data gap analysis is the US Clearing House for Inventories & Emissions Factors (CHIEF), where analyses have been made of data gaps in the information base for calculating emission factors[354]. The user of the data set uses the information on data gaps to assess reliability.

Editor's remarks on applicability of method or tool: Data gap analysis must be based on an understanding on the ecological, physical or value-based mechanism, or on reliable statistics for which data is lacking. A proper data gap analysis must therefore be performed by experts. The accuracy or credibility result is very difficult to interpret by anyone but experts, and so data gap analysis must involve some kind of expert review, certification or standardised procedure.

3.4.3 Market analysis

Market analysis, and/or listening to demands and requests from customers and other stakeholders, will inform a company about the market's willingness to pay for green product design, environmental criteria and the importance, relevance and acceptance of environmental policies and performance indicators. Consumers are a heterogeneous group and their willingness to pay for green products varies[355].

Market analysis is a tool that produces data about social values. It is either performed explicitly, i.e. by interviews with consumers/customers, or implicitly, i.e.

352 KemI (2004), *Information om varors innehåll av farliga kemiska ämnen*, page 116.
353 Pigott T D (2001), *A review of Methods for Missing Data*; Educational Research and Evaluation 2001, Vol. 7, No 4, pp. 353-383, ISSN 1380-3611/01/0704-353.
354 US EPA (1995-2004), AP 42, Fifth Edition, Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, viewed at http://www.epa.gov/ttn/chief/index.html.
355 Naturvårdsverket (2002), *Att handla rätt från början: en kunskapsöversikt om hur konsumtions- och produktionsmönster kan bli mer miljövänliga*, Swedish EPA Report 5226, page 10.

by studying sales figures and stock exchange prices. A pre-selection of the examined items, usually indicators of technical function and/or environmental effect, is made in both cases. The EPS method uses the contingent valuation method (CVM) where the willingness to pay to remedy impacts on selected "safeguard objects" is measured in interviews with OECD inhabitants[356].

Applications of the method/tool
Market analysis can be used to determine the market's environmental criteria and willingness to pay for product design, for example. An analysis of how the market's environmental criteria are created is presented in the report "*Who creates the market for environmental-friendly products?*"[357] published by the Swedish EPA. The results of the market analysis are used both by policy makers and by professional decision makers in their strategic decisions.

Editor's remarks on applicability of method or tool: The only way to judge in advance whether communication of a specific environmental performance assessment or an environmental improvement will be commercially beneficial for a product or service is to perform a market analysis. The analysis should be developed jointly by the design department, the marketing department and environmental experts, so that the answers may guide the choice of assessments or improvements, as well as communication strategies (see also section 3.2).

3.4.4 Material inventory methods and tools

Companies gain by managing product information systematically, since they can use it intelligently and avoid multiple systems, each holding product information in different formats[358]. There are standardised formats for product data, including material data such as name and weight and design data such as composition and conjunctions[359]. Some commercial organisations also supply companies with material inventory systems[360].

Applications of the method/tool
Material inventory tools can be used by professional decision makers to establish the content of hazardous substances in a product. The inventory of the materials included and their respective amounts are checked against a list of restricted substances; see 3.4.1.

The IMDS (International Material Data System) is both a material database and a tool for communicating information in the supply chain. PDM (Product Data Management) is a tool for controlling and distributing data on products. PDM systems include both data management and process management.

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[356] Steen B (1999), A systematic approach to environmental priority strategies in product development (EPS). Version 2000 – Models and data of the default method, CPM report 1999:5, Chalmers University of Technology, Sweden.
[357] Emtairah et al (2002), Who creates the market for environmental-friendly products?, IIIEE for Swedish EPA.
[358] http://www.reqio.com/whypcm.htm.
[359] http://www.md.kth.se/body/edu/mme/4F1541/exempel/Diverse/CAD-format.htm.
[360] http://www.mirsinfo.com/, http://www.adessosystems.com.

Editor's remarks on applicability of method or tool: The KemI report[361] frequently referred to in this report describes numerous ways of keeping track of the material contents of products. Hence, there is no shortage of technical or administrative solutions to this important problem. The two problems are a lack of a coordinated strategy for choosing materials to track, and the fact that the lack of such data is accepted.

3.4.5 Data input methods and tools

3.4.5.1 SCIENTIFIC MECHANISM DESCRIPTION METHODS AND TOOLS

Tools for environmental mechanisms include scientific studies of river flows, dispersal of chemicals in society, effects of nitrogen and phosphorus in specific ecosystems or purchasing patterns in different societies. A mechanism description can be written in general or specific terms.

Mechanism descriptions can be defined as precise portrayals. The primary focus when writing a mechanism description is "on the physical characteristics or attributes of a device and its parts, including information about size, shape, colour, finish, texture, and material. Such descriptions also normally include figures, diagrams, or photographs that directly support the textual discussion"[362].

Applications of the method/tool

OMNIITOX IS[363] is an example of an information system supporting transparent documentation of mechanism description and calculation for environmental impact assessment using LCA. The information system includes a fate, exposure, and effect model for toxicity assessment, including an Ecotoxicity Damage mechanism and a Human Damage mechanism. The users of the information system are environmental experts such as LCA practitioners and modellers. More information about OMNIITOX IS can be found in the example above.

Scientific analysis of mechanisms can be used with LCA and LCC studies to internalise external costs. One attempt to do this is described in the report "External Environmental Costs in LCC" by B. Steen[364]. These mechanism descriptions are generally used by environmental experts and scientists.

Editor's remarks on applicability of method or tool: Substantial expertise is needed to describe the relationship between an environmental burden of some kind, and resulting environmental impacts. It is costly to produce monitoring data and physical and ecological impact models. These models are useful for LCA practitioners and performers of EIA or EMS managers, for example, but are not intended for professional decision makers or laymen.

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[361] KemI 2004*, Information om varors innehåll av farliga kemiska ämnen.*

[362] http://www.writing.ucsb.edu/faculty/sorapure/f03/mechanism.html.

[363] www.omniitox.net, OMNIITOX project reports, Erixon M, Flemström K (2004), *OMNIITOX information system material,* and Carlson, Tivander, Erixon et al. (2004), *Conceptual model report.*

[364] Steen B (2003), *External environmental costs in LCC*, Chalmers University of Technology, found at http://www.dantes.info/Publications/.

3.4.5.2 INFORMATION MODELS FOR ENVIRONMENTAL CONTROL

PHASES (PHASEs in the design of a model of a System) is an information model for industrial environmental control describing how any model of a system can be designed. PHASES is a structure for describing all the stages necessary to bridge the gap between the first system model sketch and a full model of the system. PHASES describes how information on an entity representing a parameter of a system, e.g. inputs or outputs, starts existing at the point where the entity is defined, quantified, transformed and finally reported. PHASES defines six distinct phases through which information management takes place. Each phase uses information from the preceding phase and delivers to the next[365]. A detailed description of the phases may be found in section 4.2.2.

There are different specifications or implementations of PHASES, i.e. PHASETS, PHASENS, and PHASESS for the design of technical, natural, and social system models, respectively. The PHASETS model consists of six phases and describes how information systems for industrial production plants and information for LCI studies, for example, can be dealt with and reported systematically. The working and documentation procedures assure the quality of data in accordance with quality assurance principles under quality standards such as ISO 9001[366].

Applications of the method/tool

Environmental experts and decision makers at companies can benefit from using the PHASES model and working procedure.

The PHASETS working procedure was developed in a joint project by the Swedish Forest Industries and Chalmers University of Technology. It has been successfully implemented and tested by five pulp and paper companies.

The experience of implementation is that it improves structure and organises environmental data, as well as increasing the scope for reusing data for new applications, e.g. Emissions Trading and Integrated Product Policy (IPP). In addition, the method facilitates transparency and verification of data and can be adapted to complex as well as simple production systems and products.

Editor's remarks on applicability of method or tool: Environmental management systems are intended to protect the physical environment in the interests of sustainable development. A natural aspect of the continuous improvement of an environmental management system is thus to ensure that environmental data reflects the physical world. This costs money, but these costs cannot be avoided if the environmental management system is seriously intended.

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[365] Carlson R, Pålsson A-C (2000), *PHASES Information models for industrial environmental control*, Industrial environmental informatics, CPM, Chalmers University of Technology, Sweden.

[366] SSVL and Chalmers (2002), *Methodology for handling forest industry environmental data – Method report*, found at: http://www.dantes.info/Strategies/EnviroSupp/PHASETS/Doc/Method%20report%20%20Methodology%20for%20handling%20forest%20industry%20environmental%20information.pdf.

4 Describing environmental data and its availability

4.1 Introduction

The report "*Kunskap om produkters miljöpåverkan : tillgång, behov och uppbyggnad av livscykedata* by IVL[367], states that "environmental information" is "all conceivable and necessary environmental information relevant for products in a life cycle perspective". Hence, almost any information and data may be *environmental* since environmental considerations have a universal range, from product weight and aerodynamic properties, to biological sensitivity and global warming and to environmental priorities and legislation. Here we confine ourselves to data used for environmental decisions or assessments, focusing solely on data and information needed as input for the methods and tools presented in chapter 3. This ensures that only relevant environmental data are considered, since the scope of chapter 3 was decided on the basis of the user needs presented in chapter 2.

As the title of the report suggests, the term *primary data* plays a significant role in this report. The term was described in section 1.2.2 as "the lowest level of aggregated data needed to produce an intended piece of information". This chapter shows common and general aspects of primary environmental data, and how it can be generally formatted so that many tools can use the same or partly the same primary data.

The background information for this chapter comprises the assessments of methods and tools in chapter 3, as well as practical experience of various environmental information system development projects in which the authors have participated.

4.2 Environmental information

4.2.1 Components of environmental information

Information about environmental conditions and environmental impacts caused by industrial operations and products has intrinsically complex aspects that become practical problems when establishing databases for environmental management. This complexity arises because "environment" is a relative concept: the relationship between our noticing unwanted changes in our natural surroundings and understanding that we have caused those changes. This relativity is why environmental data are not merely measurements of natural or industrial entities. Changes in nature must instead be measured in terms of an industrial cause, and industrial processes and products must be measured in terms of their environmental significance. In addition, environmental changes refer only to those changes in nature that

[367] Naturvårdsverket (2002), *Kunskap om produkters miljöpåverkan: tillgång, behov och uppbyggnad av livscykeldata*, Swedish EPA Report 5229, p 25.

we can observe or induce from observations, not just any environmental changes. In practice, this means that facts about nature must also be considered from a given viewpoint, such as that of a specific policy maker, a specific set of voters, citizens of a specific society or a specific market. Environmental facts are not essentially objective and scientific.

Figure 11. is a high level data model showing how different information forms an environmental information unit from the relationships described above. Three disciplinary areas form an environmental information unit, whereby the Technical System represents information describing industrial processes and systems of those processes, e.g. data from engineering disciplines. The Nature System represents information describing nature, e.g. data from medical or ecological disciplines. The Social System represents information about the non-physical aspects of human beings, e.g. data from economic or humanities disciplines.

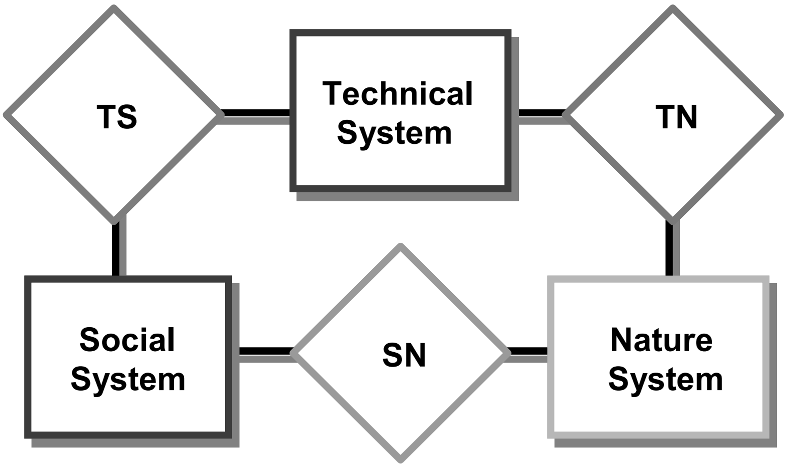

Figure 11. Three types of information join to form environmental information[368].

Data from the three disciplines also have differing roles in methods and tools. Data describing possible, real, or modelled changes in nature are explicit environmental information. Examples are ecological sensitivity, bio-indicators, etc. Data describing aspects of products or processes that may induce environmental changes are implicit environmental information. Examples are material content of products, emissions from processes, etc. Data describing observations, valuations, rankings or ratings of environmental impacts or the products derived from functions of industrial systems are subjective environmental information.

The model in Figure 11 was developed to serve as a conceptual tool to describe the nature and structure of environmental product data, including the life cycle perspective. The model is presented in further detail in "*Measuring the environmental impact of products*"[369].

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[368] Copyright Carlson R. IMI Chalmers University of Technology 1995.
[369] Naturvårdsverket (2003), *Measuring the environmental impact of products*", Swedish EPA Report 5349.

To avoid confusion, this model may be compared with the three pillars of sustainable development: economic development, social development and environmental protection[370], and with the environmental data model concept presented in "*Kunskap om produkters miljöpåverkan: tillgång, behov och uppbyggnad av livscykeldata*":

- Dividing sustainability into three main pillars means that these three must be dealt with in parallel, i.e. they describe a combined managerial goal. The model in Figure 11 is intended as a tool for sustainable development, showing how to combine data describing the value of products with data describing drawbacks. The conceptual social system in Figure 11 relates to those obtaining products from technical systems or experiencing drawbacks from environmental systems, i.e. individuals, markets, policy makers or decision makers. The two models may be combined by 1) clarifying the meaning of Social System in Figure 11 by renaming it "value system", for example; 2) in parallel with the concept of Nature System (environmental) also including the other areas of sustainability, i.e. economic and social sustainability. In this way the model can be used to integrate sustainability management into company management systems, for instance.
- The IVL report breaks down the definition of "environmental information" into "company data", "environmental data", and "qualitative environmental data"[371]. This structure may be matched with Figure 11, but only at a very high level. Hence, the same items can be found in both models, but the model in Figure 11 is operational, since it also serves as a map to describe or model existing environmental data.

4.2.2 Origins of environmental information

Understanding environmental data availability, quality and formatting requires an understanding of the nature of environmental data. In this section we suggest that environmental data is a representation of some feature of the physical world, and that there is a general description of how that data is generated. Environmental data on industrial processes and products and on changes in nature represents real features of the physical world of industry and the environment.

These data derive either from measurements of physical properties or from modelling those properties. Environmental data on social systems originate either from demographic studies or from the modelling of such studies. In practice, data also come from hybrid models, in which some data come from measurements or studies, and some from modelling. PHASES[372] is a step-by-step procedure

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[370] The Johannesburg Declaration on Sustainable Development, "Draft political declaration", Agenda item 13, World Summit on Sustainable Development Johannesburg, South Africa 26 August–4 September 2002: http://daccessdds.un.org/doc/UNDOC/LTD/N02/578/83/PDF/N0257883.pdf?OpenElement 2005-06-27.

[371] Naturvårdsverket (2002), *Kunskap om produkters miljöpåverkan: tillgång, behov och uppbyggnad av livscykeldata*, Swedish EPA Report 5229, p 25.

[372] Carlson R, Pålsson A-C (2000), PHASES Information models for industrial environmental control, CPM-report 2000:4.

describing how data is generated in practice. It has been developed to support structured, quality-managed, and systematic generation of environmental information for industrial purposes; see Figure 12.

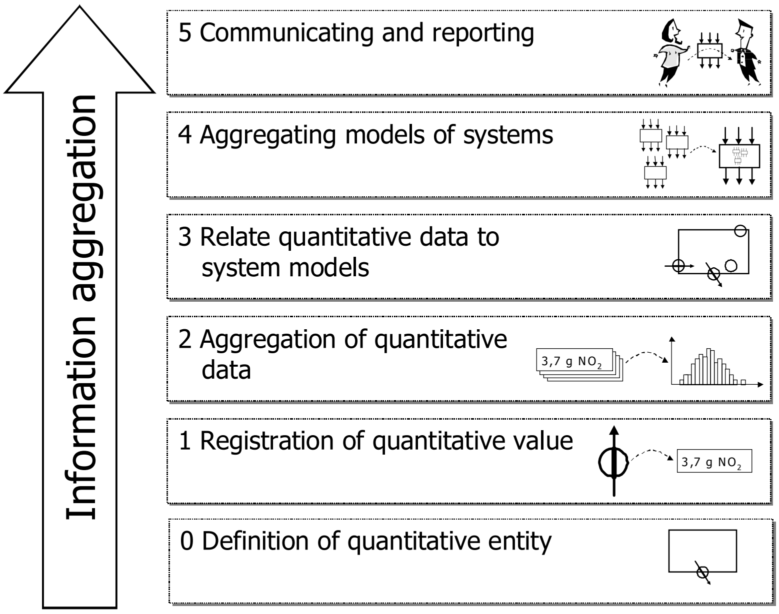

Figure 12. PHASES - PHASEs in the design of a model of a System.

PHASES has been described for acquiring data for technical systems (PHASETS[373]), for nature systems (PHASENS) and for social systems (PHASESS). The steps in the procedure described by PHASES are:

- In phase 0 an entity is defined, for which quantitative information is to be retrieved. This is the most important task of the model, both since data passed upwards through the model are based on the definition and are understood on the basis of the definition, and because the definition as such requires an overview of the system to which the entity should be related.
- In phase 1 a quantitative data item is sampled, based on the description of the quantitative entity defined in phase 0.
- In phase 2 a number of quantitative samples are statistically treated to form an aggregated quantitative value of some kind.
- In phase 3 a number of aggregated quantitative values are related to a model of the system.
- In phase 4 a number of models of systems are aggregated, either by constructing a higher-level system model from system model components, or by mathematical summation of a number of system models.
- In phase 5 the result of a phase is communicated to the person requiring the report.

373 Carlson R, Pålsson A-C (2001), *Industrial environmental information management for technical systems*, Journal of Cleaner Production, 9 (2001) pp 429-435.

PHASES is a theoretical approach to describing an empirical issue, but it also takes into account that environmental data is not always measured from physical measurements or demographic studies, for example, but rather from experts' guesses or various extrapolations or analogies.

PHASETS has been tried out in the Swedish pulp and paper industry[374] and also served as the model for the procedural guidelines for quality-assured LCA data acquisition produced by the European project CASCADE[375].

4.2.3 Sharing environmental information

The main purpose of this report is to show how primary environmental data can be shared by different applications and used for different purposes, in different applications, and in different methods and tools. Sharing data will reduce costs for redundant data acquisition and maintenance and for quality review. It will also reduce the cost of updating databases. And reducing redundancy may help to improve quality by reducing ambiguity, improving consistency and simplifying updates.

Section 2.3 introduced various environmental product perspectives: *Purchasing products*, *Designing products*, *Analysing content of product*, *Considering risks of product*, and *Societal consequence of product*. As explained in chapter 3, numerous methods and tools are needed to enable these overview perspectives, including laboratory test data, willingness to pay to avoid environmental damage and many types of engineering data and data on the behaviour and sensitivity of nature. In addition, depending on the user categories presented in section 2.2 and Table 1, different users need different information about the same perspective. A consumer may be satisfied knowing that a washing powder is eco-labelled, while a professional purchaser may need to know the detailed formula of the same product to meet water emission regulations, as well as some key life-cycle data to comply with his company's environmental policy.

Sharing primary data between methods and tools means that data acquired for a given purpose must be understood in the light of other purposes. For example, primary data collected for environmental management systems may be used for LCA; primary data for LCA may be used in design for environment, and primary data collected for emissions trading may be used for environmental labelling.

Section 4.3 presents a common data structure serving all methods and tools described in chapter 3. (The presentation continues in Appendix 2). A common data structure of this kind may serve as a bridge between primary data sources and applications, enhancing data flow and integration between methods and tools, and between primary data sources and users. Common interpretation of primary data is a prerequisite for efficient data communication in an information system (see section 1.2.2). Much of the data structure presented in section 4.3 has been tested for

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[374] Pålsson A-C, Svending O, Möller Å, Nilsson C, Olsson L, Loviken G, Enqvist A, Karlsson G, Nilseng A, *An industry common methodology for environmental data management*, SPCI 2002, 7th International Conference on New Available Technologies, June 4-6, 2002, Stockholm.

[375] Weidema B P, Cappellaro F, Carlson R, Notten P, Pålsson A-C, Patyk A, Regalini E, Sacchetto F, Scalbi S (2003), *Procedural guideline for collection, treatment, and quality documentation of LCA data*, Document LC-TG-23-001 of the CASCADE project.

industrial environmental management systems - EMS (see Appendix 1, Example 2), life cycle assessment - LCA, both complete and simplified (see Appendix 1, Examples 3 and 6), environmental product declarations - EPD, design for environment - DfE (see Appendix 1, Example 1), green procurement - GP (see Appendix 1, Example 1), and for modelling environmental characterisation of toxic substances (see Appendix 1, Example 5).

The tests have been performed by developing tools and databases for full LCA according to ISO 14040 and by using the same database structure and database contents for EMS, DfE or EDP, for example. Often the same data fields and the same data can be used, but sometimes additional fields and data contents are needed for new applications. However, since the additions are very small in comparison with what can be reused, it may be argued that the structure has proved effective for these applications.

4.3 Common primary environmental data

4.3.1 Introduction

The methods and tools described in chapter 3 require data. This section exemplifies and defines actual environmental information. In the interests of readability, the major parts of these specifications continue in Appendix 2.

Most methods and tools aggregate data in some way, and here we focus on the non-aggregated data that can be shared by different methods and tools. As mentioned in section 4.2.2, primary data is also based on aggregations of measured, modelled, or approximated data about the physical world. Here, primary environmental data is the lowest level of detailed data that can be meaningfully included in an environmental information system, method or tool.

4.3.2 Types of common primary environmental data

The model in Figure 11 requires three types of related primary: data on technical systems, i.e. industrial systems and operations; data on nature systems, i.e. environmental change and impact; and data on social systems, i.e. priorities, policy and valuation. Each is presented briefly below, and in detail in Appendix 2.

4.3.2.1 INDUSTRIAL SYSTEMS AND OPERATIONS

Examples of primary data on industrial systems and activities are:

- Substances and materials
  Physical and chemical properties, nomenclatures
- Products
  Material content data, entity property data, conjunction data etc.
- Production, transport and services
  Process models and descriptions, inputs and outputs etc.
- Scenarios, market, use and EOL
  Data on use, end of life etc.

4.3.2.2 ENVIRONMENTAL CHANGE AND IMPACT

Examples of primary data about the nature system are:

- Descriptions of natural systems subject to impact or risk.
- Quantifiable environmental indicators.
- Quantifiable environmental aspects of human activities.
- Quantitative data on how environmental aspects relates to indicators.

4.3.2.3 PRIORITIES, POLICY AND VALUATION

Examples of primary data about the social system are:

- Demographic identification of social systems.
- Subjective choices, viewpoints and priorities of demographic groups or individuals.
- Clearly stated principles as to why specific environmental impacts are considered.
- The environmental policy of a company.
- Scientific or philosophical world views or system conditions[376, 377]
- Sweden's 15 environmental quality objectives[378].
- Life-cycle impact assessment weighting factors.
- Environmental target values or environmental performance values in relation to them.

4.3.3 Data Formats and structures

Primary data is only useful if placed in a good data format. A data format is designed for a purpose, e.g. to structure a data form, a questionnaire, a database, or a software file or for the purpose of exchanging data between formats. A format specifies the meaning and the content of data fields and how they are related to each other. Data formats differ in their intended purpose, and the meaning and the structure of the fields are different.

When exchanging data between differently formatted data sources or applications, it is possible to use either one of the formats as a master format, or use an independent third format as an exchange format. In either case, a structured match between the formats is needed, but where there are many formats, the use of a neutral third format is most efficient, since each match is then needed only once.

It is not efficient to replace different data structures that are used in different applications and organisations throughout society with a single common structure. A new common format should be used to aid translation and communication between data sources and applications. However, new environmental information systems ought to be developed on the basis of common structures and formats for primary data.

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376 Holmberg J (1998) *Backcasting - a natural step when operationalising sustainable development*, Greener Management International - the Journal of Corporate Environmental Strategy and Practice. Issue 23: 30-51. (Autumn 1998).

377 Holmberg J (1995), *Socio-Ecological Principles and Indicators for Sustainability*, Ph.D. Thesis, Institute of Physical Resource Theory, Chalmers University of Technology and Gothenburg University, , Sweden .

378 Miljömålsrådet, http://www.miljomal.nu/english/background.php.

Examples of how primary data may be structured for formatting will be given in the following three subsections. The primary data considered in these examples are *Naming and nomenclatures*, *Quantification* and *Indicators*. These have been chosen because they are general and applicable to all three types of common primary environmental data (section 4.3.2). Appendix 2 contains much more detailed descriptions of the three types of primary environmental data needed to describe environmental product life cycles.

4.3.3.1 NAMES AND NOMENCLATURES

Natural communication between people is impeded when things are named differently in different situations. But the problem does not become serious until communication should be quick and automatic, as in routine environmental work in government or industry or in computerised environmental data handling systems. Thus, terminology is central to the smooth handling of environmental information.

There are many concurrent naming conventions and nomenclatures for the same things. For example, a material may have a completely different name when used in different contexts and for different purposes by various companies or other organisations. For instance, carbon dioxide is correctly named *carbon dioxide, CO_2, koldioxid'*[379] in different situations. Understanding names when standardisation is not feasible may be aided by adding a definition to the name, and by relating the name to the nomenclature or the context in which it is used. This will make the name easier to interpret when mapped between formats. Here we mean that, in practice, a nomenclature is a system of names used in a specific context[380].

Figure 13 describe how a data structure may be designed so that forms, questionnaires, databases, software or neutral data transaction formats can support understanding and resolve ambiguities of this kind; A "real world" item is described by the myriad "names" that different users have for it. This could be done as a list of names, without further specification. But the understanding of each alternative "name" is improved by also referring to its "nomenclature".

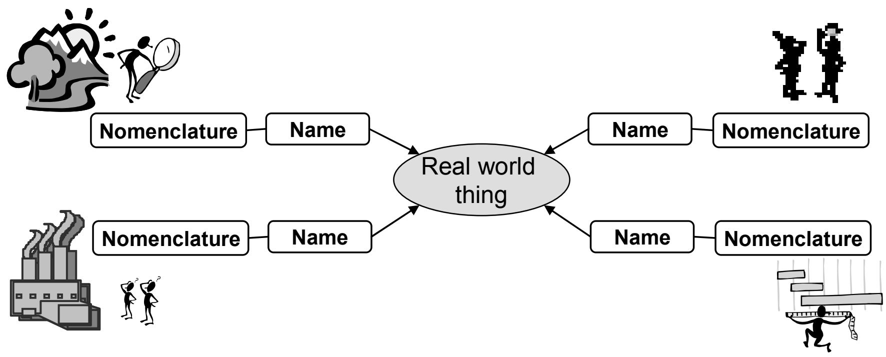

Figure 13. Data structure for names and nomenclatures. A thing may have many different names. Each name belongs to nomenclaturem which provides a context for the name. This way of structuring the different names and contexts can be seen as a “uniformity filter" bridging the gap between data from different contexts.

[379] Flemström K, Geiron K, Erlandsson M (2004), Industrial applications of future information systems for impact assessment A procedure for data format mapping and nomenclature issues, CPM Report 2004:5, Chalmers University of Technology, Sweden.

[380] www.dictionary.com.

The example of three concurrent names would look something like "*English language - carbon dioxide; chemical notation - CO_2; and Swedish dictionary – koldoxid*". More details about data formatting and structuring of names and nomenclatures are given in Appendix 2.

4.3.3.2 QUANTIFICATION

Most of the methods and tools presented in chapter 3 use different quantitative primary data as input and also produce quantitative output. Quantitative input values are based on empirical observations or some sort of modelling, and they involve uncertainties. So, to obtain correct results with correct uncertainties from calculations, the primary data should be supplied with uncertainty information. But in reality, most available methods and tools cannot perform uncertainty calculations, and uncertainties are not available for most primary environmental data. Thus, for most practical applications, quantities of environmental data are currently expressed as simple single values; statistical facts are absent. This is satisfactory in practical or scientific terms, and any format for environmental data or information should therefore be structured to conform to statistical parameters.

Appendix 2 presents a data structure flexible enough to accommodate any statistical data, ranging from mean value, full sampling sets or any advanced distribution function.

4.3.3.3 INDICATORS

Section 1.2.1 described many ways of expressing condensed and simple environmental information, e.g. as key environmental aspects, environmental performance indicators, environmental condition indicators, category indicators, data categories or reporting variables. For the purpose of data structuring, these differently named information items are basically the same; they are to be defined and described in similar ways. For ease of understanding we here refer to all of them as indicators, but are aware of the distinctions between these names in different applications and situations. Figure 14 shows a data structure for primary data on indicators, in this broad sense.

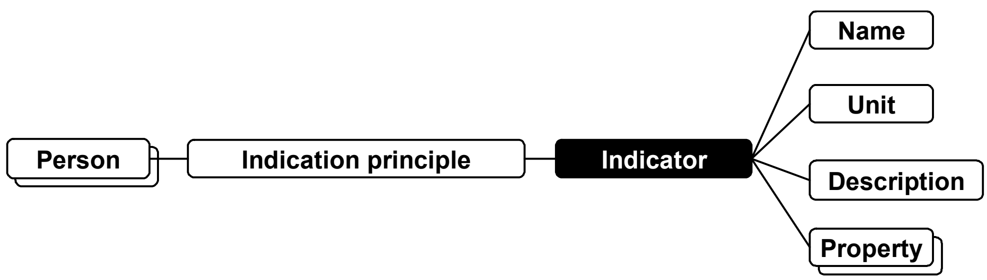

Figure 14. Data structure for indicators

An indicator has a *Name* used to refer to it in speech or writing, for example (see also subsection 4.3.3.1), as well as a *Description* denoting more graphically what it stands for and what it represents. To understand a specific indicator, it is very useful to know what *Person or organisation* has defined it, and for what purpose and from what standpoint (*Indication principle*). This information about policy and subjective standpoints makes it easier to understand whether the indicator is intended for public health, biodiversity, strategic sustainable development, hardware design, annual management goals at a company, or as procurement guideline indicators for professional purchasers in a given sector.

Since indicators are intended for some sort of quantification, the intended quantitative *Unit* is also needed. For some purposes indicators may need to be further specified in terms of different dimensions or *Properties*. For example, indicators describing public health may need to be specified in terms of "lost labour productivity", "reduced quality of life" or "years of lost life", and biodiversity may need to be specified in terms of e.g. "lost number of species", "lost ecological productivity" or "geographical area affected".

4.4 Availability and interpretability of environmental data

4.4.1 The concept of "availability"

There is no general answer to the question of whether or not data is available, since availability as a concept involves many aspects, and data availability varies so much, depending on type of data in focus and particularly the purpose for which it is intended. Some data are abundant, but for a given purpose it may be very hard to find the right data.

For example, LCA data on many types of plastic are available at the APME (Association of Plastics Manufacturers in Europe) website[381], e.g. polyvinyl chloride, polymethyl methacrylate, nylon. A common guideline for LCA practitioners is to turn to this organisation when data on plastics production is required for a study. Nevertheless, it is a fact that the current total supply of plastics in society is not represented at this LCA data source. Hence, LCA practitioners need data for plastics that are not available there. Moreover, LCA data on polycarbonate, for example, derive from 1992 - 1996 and were over ten years old at the time of writing. Also, the APME LCA data are European averages and do not apply for LCA studies for specific suppliers of plastic components. In some respects LCA data on plastics are available, but in others not. There are thus many aspects of environmental data availability to consider. We list six here:

- *Existence*, i.e. whether anyone has ever structured this specific type of data, whether it be toxicological data expressed as risk phrases, LCI data on cement production, or cause-effect modelling of CO_2 emisisons, into e.g. a database, a report or a call service.
- *Coverage*, i.e. the extent to which data cover the exact needs, e.g. whether risk phrases for all chemicals in my scope are provided, or perhaps only 30 per cent. Coverage may also depend on the selection

381 http://www.apme.org.

principles used when acquiring data. The reason for acquiring LCI data for cement production could be to create a scenario for a new production facility in North America. Those data may not be relevant for an LCI study focusing on average cement production in Sweden.

- *Understandability*, i.e. whether the data are documented so that they can be interpreted by a user. For example, a product developer needing toxicological data expressed as risk phrases for his design for environment-tool may have difficulties in understanding toxicology terminology. Further, it is crucial that the data be available in a language that the user can appreciate.
- *Maintenance*, i.e. whether there is anyone to contact to obtain more information about the data. It may be possible to increase the coverage, or to gain a better understanding of the data by putting questions to an administration, a person that has documented the data, or someone who just knows more about this particular kind of data.
- *Accessibility*, i.e. whether the data are actually accessible for the user in terms of cost, secrecy issues, etc. If the requested data are documented in a company's internal report on commercial strategies, product recipes, etc., they might be difficult to obtain. Someone will have to go through the document, decide what to publish and how to separate the confidential information from the public information. This is time-consuming and may not be done, particularly if the data supplier does not benefit in some way.
- *Formatting*, (see section 4.3.3), i.e. whether the data is separated in specified data fields in the documentation, or whether it is available only in free text in literature or structured in databases. If the information is only available in free text, someone will have to read it, interpret it, and extract exactly the information needed. Thus, if a large amount of data is needed, this will be a very time-consuming and expensive task. It may also be difficult to find a person capable of interpreting the information correctly; see *Understandability*.

Experience has shown that it is difficult to judge actual availability without testing the data sources in real cases. One way of doing this is to look from the viewpoint of a specific indicator (see section 4.3.3.3) and to start a data acquisition task in the form of a limited and well-defined project, by performing a data inventory, where one part should be to test the availability of the suggested data sources. This was tested in the EU project OMNIITOX[382] between 2002 and 2003. By testing the availability of the data in the suggested data sources, an early indication of the outcome of the data acquisition, and in fact the project as a whole, was

[382] OMNIITOX – Operational Models aNd Information tools for Industrial applications of eco/TOXicological impact assessments, see www.omniitox.net for more information about the project and its results.

presented[383]. The success of projects involving data acquisition depends on a good understanding of real data availability and on data methods.

A realistic balance between aims and realism is a success factor, since many of the putative available data sources fail to meet one or more of the availability criteria listed above. Below we nonetheless attempt to describe the general availability of the data types described in the previous sections, concentrating particularly on *Existence*, since the requirements of each new application may render any given data source useless.

4.4.2 Availability of various types of data

As mentioned above, data availability varies depending on the type of data studied. The availability of certain kinds of data is discussed in this section. The types of data that a decision maker, expert, or any other user needs derive from the technical, environmental, and social system[384], and are here described in terms of:

- **Industrial systems and operations**, such as
  Materials, product and design
  Production and transport
  Scenarios, market, use and EOL (End Of Life)
- **Environmental change and impact**, such as
  Indicators
  Nature systems compound
  Change and sensitivity models
- **Priorities, policy and valuation**, such as
  Selection of indicators
  Target and reference values

In some cases, data sources for a certain type of data are listed. The list is not exhaustive; it should be viewed as presenting examples of data sources.

4.4.2.1 INDUSTRIAL SYSTEMS AND OPERATIONS

Data on industrial systems and operations have been acquired and used for a very long time, even though the aim has been other than sustainable industrial society. Reasons for acquiring and using these data could be legislative requirements, quality control, financial reporting, production optimisation, etc. This means there is a considerable amount of data on industrial systems and operations. However, when it comes to the coverage in an LCI or DfE context, for example, the data are not always as usable as might be imagined at first glance. One example is the Swedish environmental reports, which are submitted by industry to local authorities according to legislation. One of the problems of using this information is that emissions, energy use, etc.do not have to be related to a functional unit. Reports are usually submitted annually, emissions being presented as average values. Thus, if several

[383] Erixon et al. (2003), *Data Source Inventory Report*, OMNIITOX project report, available at www.omniitox.net.
[384] Naturvårdsverket (2003), *Att mäta produkters miljöbelastning*, Swedish EPA Report 5269.

products are manufactured, severe allocation problems will be one of the obstacles for an LCA practitioner using this information[385].

Materials, product and design

In Appendix 2, section 2.1.1 common nomenclatures for material names have been identified as necessary to obtain a result from any of the tools and methods described in chapter 3, and to make it possible to exchange data or use the same information in a different context. There are many material nomenclatures; examples include CAS number[386] , EINECS number[387] and IUPAC Name[388]. More examples are listed and described in Appendix 3.

There are many material nomenclatures, which have all been developed for use in a specific context. Environmental assessments often require information from many areas and hence contexts. Consequently, a great deal of time is spent translating material names between nomenclatures. An efficient and integrated approach requires mapping between relevant nomenclatures, although this might be a drain on resources and should be performed systematically.

Section 4.3.4.1 identified a need for knowledge of the material content and component structure of products. A data model was also provided on the basis of those needs. This enables this kind of primary environmental data to be stored and communicated in a general format.

The material content and composition of a product are largely decided in the design phase; see 2.3.2. This information is important for manufacture of the product and in contact with sub-contractors. It is also needed to provide spare parts for manufactured products. For this reason information systems often already exist. These can be used to deal with this kind of information at companies. Information on colour, shape, and the composition of various structures is often stored in a CAD (Computer Aided Design) system, and information on material choices, component structures etc.is often stored in PDM (Product Data Management)[389] systems. The contents of the systems often vary from company to company. In addition, this kind of information is often also needed for company functions such as safety, health and environmental support; see 2.3.4. But the information requirement for these functions is often not met by the existing information systems used in product development and production as described above. Instead these functions collect the information again, often without coordination between the various functions. This adds to the cost of the data collection procedure, and also means that the results of the assessments are not available until late in the product development process and thus cannot influence product design to any great extent. It is costly to alter the design of a product that has come far in the product development process; see 2.3.2. One way of ensuring that sustainability is considered early in the product

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385 Erixon M, Ågren S (1997), *Miljörapporter som underlag till livscykelanalys*, CPM Report 1997:5, Chalmers University of Technology, Sweden.

386 CAS, http://www.cas.org.

387 ECB, *European Inventory of Existing Commercial Substances EINECS*, viewed at http://ecb.jrc.it/existing-chemicals and http://ecb.jrc.it/esis/esis.php?PGM=ein&DEPUIS=autre.

388 International Union of Pure and Applied Chemistry http://www.iupac.org.

389 PDM: http://www.ivf.se/ivfTemplates/WorkAreaDescription____275.aspx.

development process is to introduce sustainability aspects in a Gate model as described in 3.3.1.2.

As mentioned above, existing information systems for product development and manufacture do contain a large amount of information needed for environmental assessments. But they do not contain all the information needed. An example of information often missing in these systems is detailed information on the material content and component structures in components supplied by subcontractors. From a design perspective, neither the contents of the components nor information on how they have been produced are relevant, as long as they comply with specifications, (e.g. size, weight, energy consumption and tensile strength) for the component decided in the design. So information must often be collected from suppliers specifically for functions such as safety, health and environmental support. This information gathering often lacks any financial incentive for the giver, which makes it hard to obtain the required data. In addition to the extra cost of collecting data, sub-contractors may have other motives for not providing the required information. For instance, the material content of a component supplied may be a trade secret. Information about products supplied by sub-contractors should always be delivered together with the product[390]. Implementation of this approach is facilitated by specifications in the business agreements between the buyer and its sub-contractors. The automotive industry uses a system called IMDS (International Material Data System)[391] to collect data on the material content of all components supplied by sub-contractors.

Material property data or substance property data are needed to address safety, health and environmental issues or to measure the environmental performance of the product at many manufacturing companies as described in section 2. This information can be used to produce safety data sheets or other health, safety or environmental product information documents for customers and suppliers.

There are many databases containing substance property data. Some of them contain toxicity data and are described in section 4.4.2.2. There are other types of substance or product property databases such as Chemical Substances[392] and the Combined Chemical Dictionary[393]. More examples and a description of each can be found in Appendix 3.

Production and transport

The environmental assessment of products and services calls for LCI data on the processes falling within the scope of an analysis. These data should ideally be specific to each process involved in the production of a product or service. However, since it is expensive to acquire product-specific information, there are databases containing LCI data, which, if found suitable, can be used instead of the specific data on a technical system; see 4.3.4.2. For example, if an LCA practitioner cannot obtain information for the production of a specific component from a supplier, he

[390] Carlson, Erixon, Forsberg, Pålsson (2001), *System for Integrated Business Environmental Information Management*, Advances in Environmental Research, 5/4 p. 369-375.
[391] IMDS website: http://www.mdsystem.com/html/en/home_en.htm.
[392] Chemical substances, www.prevent.se.
[393] ChemNetBase, http://www.chemnetbase.com and http://www.chemnetbase.com/scripts/ccdweb.exe

or she may use data on the production of a similar product, or perhaps average production data for the component, which is available in an LCI database. Examples of LCI databases are **EcoInvent[394] and LCA@CPM[395]**. More examples can be found in Appendix 3.

Details of product contents, which are needed to analyse the environmental impact caused by the manufacture of a product, can often be retrieved from other related systems at a company as described in the previous section.

The environmental assessment of products and services also calls for data on the transport included in the scope of an analysis; see 4.3.4.2. Publicly available information provides detailed data on the environmental load caused by transport using different modes of transport. Examples of these information sources are Emission Calculation tool provided by Schenker[396] and NTMCalc[397]. More examples and information about them can be found in Appendix 3.

Scenarios, market, use and EOL

Section 4.3.4.3 identified downstream data on the environmental burden caused by a product or service in the use and end-of-life (EOL) phases as a need to achieve a result from many of the assessment tools described in chapter 3. This kind of information is generated using support tools such as market analysis, as described in 3.4.3. Another effective method of generating information about the future is scenario modelling as described in 3.3.2.1, where the effect caused by an event on a selected set of indicators in a clearly defined system is studied. Also, downstream information can be generated on the basis of monitoring of products when they are used in a controlled environment under suitable test conditions. For example, a test environment with extreme conditions can be used to acquire data on what could happen to the product in a worst case scenario.

Data on the use phase must generally be generated for each product or product group. No good examples of information sources covering the use phase of products or services could be found, even though some use cases can be found in LCI databases; see previous examples in this chapter.

Data on the EOL of a product is available in some databases, for example the United States Geological Survey: "Commodity Statistics and Information" online database[398] and the International Iron & Steel Institute: "World steel in figures" online publication [399]. More examples and more information about these sources can be found in Appendix 3.

Data on the EOL treatment of products is very closely related to the economic value of the materials in the product. The availability of data on the economic value of materials is very good. Examples of information sources covering these areas are the London Metal Exchange[400] and the New York Mercantile

394 EcoInvent - http://www.ecoinvent.ch.
395 LCA@CPM - http://kakapo.imi.chalmers.se/nukes/index.html.
396 Emission Calculation tool provided by Schenker - http://www.btl.se/schenker_btl/about/environment/english/calculation.html.
397 NTMCalc - http://www.ntm.a.se/ntmcalc.
398 http://minerals.usgs.gov/minerals/pubs/commodity.
399 http://www.worldsteel.org.
400 London Metal Exchange - http://www.lme.co.uk.

Exchange[401]. More examples and a description of the availability of these sources can be found in Appendix 3.

As described in 3.4.1.6, databases containing scenario information are very hard to find. Such information is instead acquired as single events for specific studies, or on a more general scale at various institutions, companies etc. participating in futures studies or future aligned consultancy, for example the Institute for Prospective Technological Studies (IPTS)[402] and the World Future Society (WFS)[403] . More examples and a description of their availability can be found in Appendix 3.

The availability of data on future conditions is often insufficient to allow scenario modelling of relevant quality at an acceptable cost. Common databases containing information on desired future structure of society is needed to create relevant scenarios. For example, municipalities should be able to provide information on waste management systems of the future.

4.4.2.2 ENVIRONMENTAL CHANGE AND IMPACT

According to the report "Measuring the environmental impact of products"[404] information on environmental impact is difficult to find. There are individual sources at local non-governmental organisations, research groups and authorities, but there is no coordination of these sources. One good model for coordination of this kind can be seen in the OMNIITOX project[405]. This project coordinates knowledge and information from toxicologists and modellers of environmental impact. It should likewise be possible to coordinate information about issues such as the greenhouse effect, acidification and eutrophication so that it can be used in a uniform way for a quantitative life cycle impact assessment. Information for weighting may be possessed by consumers, non-governmental organisations and public authorities. Consumers choose products on the basis of their evaluations; non-governmental organisations have a purpose with their activities, and authorities formulate objectives, e.g. the Swedish environmental quality objectives. In this context, however, there is a pressing need for policy development, in which clearly-defined approaches are established, reflecting a coherent, long-term strategy[406].

Indicators

As pointed out in Appendix 2, section 2.1.1.1, an environmental condition indicator is a quantifiable entity in the "nature system". Every time an indicator is defined, a new entity is born. The environmental condition indicators at a company must be relevant for the company's operations, but still allow comparisons with other companies and sectors. Sets of indicators have been developed by many organisations, their contents ranging from a handful of general indicators to hundreds of specific ones. The advantage of general indicators, such as the set developed by WBCSD

[401] New York Mercantile Exchange - http://www.nymex.com.
[402] http://www.jrc.es/home/index2.cfm.
[403] http://www.wfs.org.
[404] Naturvårdsverket (2003), *Att mäta produkters miljöbelastning*, Swedish EPA Report 5269
[405] OMNIITOX – Operational Models and Information tools for Industrial applications of eco/TOXicological impact assessments, see www.omniitox.net for more information about the project and its results.
[406] Naturvårdsverket (2003), *Att mäta produkters miljöbelastning*, Swedish EPA Report 5269.

and GRI[407], is that they are relevant to nearly all organisations whatever their genre and therefore allow comparisons. The disadvantage is that they are poor measures of the environmental performance of most companies, and there is a need for additional, company-specific, indicators capable of providing an accurate appraisal of the organisation's performance[408]. Examples of publicly available sources for indicators are GRI and WBCSD[409], ISO 14031[410] and Swedish EPA[411, 412]. Details of the availability of each of these can be found in Appendix 3.

Nature systems compound
The information available on the nature system is largely based on geopolitical boundaries such as nations or municipalities level. Hence, the geographical validity of data does not always match the boundaries applying in environmental impact assessment models.

The data used for environmental impact assessment information models varies greatly depending on the methodological range considered in the models. Examples of data sources with measured data possessing nature system properties are

- nomenclatures for identifying geographical locations including **GIS**[413] positioning data;
- national institutions such as **SCB**[414], with data on food production, irrigation rates, etc;
- national institutions such as **SGU**[415] and **SMHI**[416] maintain databases on river flows, distribution of soil types, air temperatures, precipitation, etc.

Data from specific studies can be extracted from scientific articles and reports, environmental impact assessment reports, etc.

Change and sensitivity models
Risk assessment requires information on the toxicological aspects of substances, as described in section 4.3.1.3. Examples of data sources covering this area are TOXNET[417](a search portal to toxicological databases), IRIS[418] (containing toxicological effects data on chemicals) and ESIS[419]
containing risk assessment reports and data on chemicals.

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407 Verfaillie H, Bidwell R (2000), *Measuring eco-efficiency - a guide to reporting company performance*, World Business Council for Sustainable Development, http://www.wbcsd.ch/web/publications/measuring_eco_efficiency.pdf.
408 European Commission (2003), 2003/532/EC, Commission recommendation of 10 July 2003.
409 Verfaillie H, Bidwell R (2000), *Measuring eco-efficiency - a guide to reporting company performance*, World Business Council for Sustainable Development, http://www.wbcsd.ch/web/publications/measuring_eco_efficiency.pdf.
410 International Organisation for Standardisation (1999), ISO 14031: Environmental management - Environmental performance evaluation – Guidelines.
411 http://www.internat.environ.se/index.php3?main=/documents/objectiv/objectiv.htm.
412 Miljömålsrådet, http://www.miljomal.nu.
413 Geographic Information System, http://www.gis.com.
414 Statistiska Centralbyrån SCB, http://www.scb.se.
415 Sveriges Geologiska Undersökning SGU, http://www.sgu.se.
416 Sveriges Meteorologiska och hydrologiska Institut SMHI, http://www.smhi.se.
417 TOXNET - http://toxnet.nlm.nih.gov.
418 IRIS - http://www.epa.gov/iris/index.html.
419 ESIS - http://ecb.jrc.it/esis.

More databases containing toxicity data have been reviewed and analysed in the OMNIITOX project, in the report entitled Data Source Inventory[420]. Results from the OMNIITOX project also show that there is a chronic shortage of toxicological data on existing chemical substances and of nature property data needed to perform risk assessments studies[421]. The need for data in this field often exceeds its availability.

Characterisation in LCA links the inputs and outputs of the technical system with their impact on the quantitative environmental condition indicators. In other words, it is the mechanism linking cause to effect in a quantifiable way. This is done using characterisation models, including fate, exposure, and/or effect models. Examples of data sources for characterisation models are EcoIndicator 99[422], EDIP[423, 424] and EPS2000[425]. More examples and a short description of each are given in Appendix 3.

These characterisation models are available as characterisation factors, where the quantitative relationship between an input or output from anthropogenic activities and an indicator in the nature system are aggregated to form a single factor. This means that the data input to the model is fixed and cannot be easily exchanged or updated, which makes the models quite inflexible. Moreover, characterisation models must be used with care, so that both the input and output from the technical system in focus, and the relevant environmental condition indicator, match the model[426, 427]. For example, in practice a model for emissions to air of nitrogen oxides (NOx) does not match an outflow of nitrogen to aquatic systems. Matching difficulties are very common and require a great deal of work on nomenclature correlation and interpretation of models. These problems can also lead to inaccurate results. However, the correct match is simplified if all relevant information is documented about the inputs and outputs as in 4.3.4.2.2, and about the load envisaged by the impact model as in 4.3.5.2.

4.4.2.3 PRIORITIES, POLICY AND VALUATION

Environmental concerns are all formulated by humans. Since opinions differ depending on background, interest, knowledge, context, etc., the important issues selected by one person may differ from the objectives of another. Even though

[420] Erixon et al. (2003), *Data Source Inventory Report*, OMNIITOX project report, available at www.omniitox.net.

[421] Erixon M et al (2003), *Data acquisition report*, OMNIITOX Project Report, Industrial Environmental Informatics (IMI), Chalmers University of Technology, Gothenburg, Sweden.

[422] Goedkoop, Spriensma (2000), The Eco-indicator 99: A damage-oriented method for Life Cycle Impact Assessment Methodology Report, Second edition.

[423] Hauschild, Wenzel and Alting (1997), Environmental assessment of products Vol. 1 Methodology, tools and case studies in product development, London Chapman & Hall.

[424] Hauschild, Wenzel (1998), Environmental assessment of products Vol. 2 Scientific background, London Chapman & Hall.

[425] Steen B (1999), A systematic approach to environmental priority strategies in product development (EPS). Version 2000 – Models and data of the default method, CPM report 1999:5, Chalmers University of Technology, Sweden.

[426] Erixon M et al, (2000), Facilitating Data Exchange between LCA Software involving the Data Documentation System SPINE, CPM Report 2000:2, Chalmers University of Technology, Sweden.

[427] Erixon M (2001), Information system supporting a web based screening life cycle assessment tool CPM Report 2001:14, Chalmers University of Technology, Sweden.

these concerns are central to any kind of environmental assessment, this information is rarely explicitly documented, particularly not in relation to the assessment tools available. To make environmental friendly decisions, the decision maker must have information on what is considered good and what is considered important. Often the decision maker can only rely on his experience and opinions. At the other end of the spectrum, he relies on the opinion of a policy maker or a scientific modeller's opinion by using generally applicable and available impact assessment models. If this is done without knowing what the concerns represent and how they are prioritised, the result may be sub-optimal decisions.

Selection of indicators

The choice of how to express or indicate environmental impact is subjective and depends on the viewpoint of an observer. This viewpoint may be expressed as a principle: the "impact indication principle".

Reasons for choosing indicators may be found in policy documents such as that governing the environmental objectives defined by the Swedish Parliament[428]. Companies usually document these reasons in their environmental policy. However, in many cases the link to quantifiable indicators is not explicitly stated in the policy but may be documented in company action plans for implementing the policy. But a common situation is that this information is not considered or documented at all, which results in an unknown correlation between the issues addressed in the policy and what is actually being monitored in operational environmental assessment.

Scientific studies have been made to define sustainability models intended to serve as a basis for all environmental concerns, such as the four system conditions[429, 430] defined by the Department of Physical Resource Theory at Chalmers.

According to ISO standards 14040-43, an LCA describes the impact indication principle in the Goal and Scope part of the study. In addition, the documentation of characterisation models created for general use in LCA, such as EDIP, EPS2000, set out reasons for the environmental concerns and choice of indicators. However, that information is generally not presented together with the resulting characterisation factors from the model in commercial LCA software, which may make it difficult to understand what the results of the characterisation actually represent.

Prioritisation and weighting

Relative information on how much we care about an environmental issue can be found in policy texts in terms of the concerns given priority. This can be further specified as information as to which concerns to give priority, as in the product requirements example in Table 9, chapter 4.3.5.2.

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428 Environmental Objectives – background http://www.miljomal.nu/english/background.php.

429 Holmberg, J (1995), *Socio-Ecological Principles and Indicators for Sustainability*, Ph.D. Thesis, Institute of Physical Resource Theory, Chalmers University of Technology and Gothenburg University, Sweden.

430 Holmberg, J (1998), *Backcasting — a natural step when operationalising sustainable development*, Greener Management International. — the Journal of Corporate Environmental Strategy and Practice. Issue 23: 30-51 (Autumn 1998).

Comparability within a set of concerns in absolute terms requires quantified weighting factors for the indicators representing those concerns. Weighting factors are defined for many impact assessment tools and can be expressed in monetary terms, or in another comparable unit such as environmental load unit (ELU), as defined by the EPS2000 method. They also help the decision maker to interpret the quantified impact. Another example is the method for weighting developed by the Japan Environmental Policy Priorities Index Forum, JEPIX[431], which is based on the "distance to target" principle.

Goal and reference values
Sustainability is a moving target. Opinions on what is considered sustainable change as we learn how nature responds to human actions, as the human population grows, and as our technology develops. Since we cannot achieve sustainability overnight, it is useful to set achievable goals to guide us in our present situation.

Details of specific goals can be found in political agreements such as in the Kyoto Protocol[432], which requires a reduction in greenhouse gas emissions in absolute terms by the signatories. Goals may also be documented as environmental performance standards and communicated to a product developer or a supplier. Quantitative goals can also be documented in protocols for a company's EMS as stepwise goals for the continuous improvements of its environmental performance.

Reference values are found in regulatory frameworks such as the Technical Guidance Document on Risk Assessment[433] or as threshold values for water quality for public drinking water[434, 435]. The reference values are accompanied by procedural requirements, e.g. if the risk assessment reveals a quantitative impact greater than the reference value, risk management action must be taken, or if the water quality exceeds a certain threshold, consumers must be informed.

Target or reference values are often not explicitly documented, since they are often referred to as "common sense", which may cause problems if they are used or interpreted by someone else. Even updating or changing reference values is easier if documentation of previous values can be found.

4.4.3 Conclusion - primary environmental data availability

As described in section 4.4.2, there is plentiful environmental data, much of which may be considered primary data and a meaningful input for the methods and tools described in chapter 3. In a general sense, therefore, data exist for the various user needs listed in chapter 2. But, as described in section 4.4.1, there are many factors to consider as regards actual environmental data availability. Some of these are

431 http://www.lci-network.de/cms/content/cache/offonce/lang/de/pid/643.
432 UN (1997), Kyoto Protocol to the United Nations framework convention on climate change.
433 ECB (European Chemical Bureau) (2003), Technical Guidance Document in support of Commission Directive 93/67/EEC on Risk Assessment for new notified substances, Commission Regulation (EC) No 1488/94 on Risk Assessment for existing substances and Directive 98/8/EC of the European Parliament and of the Council concerning the placing of biocidal products on the market, viewed at http://ecb.jrc.it/cgi-bin/reframer.pl?A=ECB&B=/Technical-Guidance-Document.
434 European Council (1998), Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption, Official Journal L 330 , 05/12/1998 P. 0032 – 0054.
435 Livsmedelsverket (2001), *Livsmedelsverkets föreskrifter om dricksvatten*, SLVFS 2001:30.

general and may be considered by assessing the data source, but some relate to the specific application and user. And it is not an economic proposition to assess any data source or data availability unless user relevance is assured. Hence, data availability must be assessed in terms of real needs, such as by data acquisition projects, or from the viewpoint of priority indicators. When an indicator is decided, it will be possible to ascertain whether all relevant methods and tools, expertise and primary data are truly available.

Data availability and indicators may be set in an iterative way, so that an initial indicator candidate is used to make a feasibility study, the result of that study being used to further define the candidate, and so on. As a result, an actual indicator may be decided and clearly defined. All expertise, methods and tools may be clearly identified, and available data sources and those requiring further development may both be clearly selected.

Hence, to increase data availability for environmental overview of product life cycles throughout society, long-term environmental indicators of this kind should be determined at various strategic levels, such as the UN and World bank, the USA, EU and other regional unions, by countries, sectors and by those engaged in public procurement and consumption. Indicators should be set to serve as long-term targets and to drive action plans towards improved data availability. Cooperation should be established and expertise should be made available to support synergetic definitions of indicators, so that primary data sources and expertise may serve as many purposes and applications as possible.

Definition of strategic and synergetic long-term indicators is a key task for proponents and stakeholders of environmental product life cycle overviews.

5 Organising an information system

5.1 Introduction

In the report produced by the Swedish Environmental Research Institute (IVL) [436] an overall strategic coordination model for site-specific and generic LCI and LCA databases, expertise and tools is described. In the report produced by the Swedish Chemicals Inspectorate (KemI) the need to use suitable information technology to ensure that primary environmental data[437] is communicated consistently throughout the product chain is identified [438].

The information system described in this chapter is intended for all methods and tools needed for environmental product life cycle overview (chapter 3), and thus has a wider scope than LCA methods examined in the IVL report. This chapter provides fewer technical details on information system components than the KemI report.

But the most significant difference between previous descriptions of information systems for environmental product life cycle overview and the one described here is the practical approach to organising the functions of the information system, such as the acquisition and maintenance of primary environmental data, access to environmental expertise, selection and combination of methods and tools, establishment of communication channels and identification of users and user requirements for the information. The practical approach is based on identification of user requirements and on voluntary agreements between data providers and developers of methods and tools. The overall principle for the information system was described in section 1.2.2.

The contents and structure of this chapter are largely based on the users and applications presented in chapter 2, the methods and tools in chapter 3 and the data formats and available data in chapter 4. The information system designs and design principles result from project results and from the new knowledge established in the new interdisciplinary field called "industrial environmental informatics" since 1996. Some of these are presented in the Swedish EPA report "*Measuring the environmental impact of products*"[439], and other results can be accessed through the website of the research group Industrial Environmental Informatics - IMI at Chalmers[440].

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436 Naturvårdsverket (2002), *Kunskap om produkters miljöpåverkan: tillgång, behov och uppbyggnad av livscykeldata*, Swedish EPA Report 5229, 69 pp.

437 "chemical property information".

438 KemI 2004, *Information om varors innehåll av farliga kemiska ämnen*, 40 pp.

439 Naturvårdsverket (2003), *Measuring the environmental impact of products*, Swedish EPA Report 5349.

440 Industrial Environmental Informatics IMI, http://www.imi.chalmers.se.

5.1.1 Basic requirements and design principles

When implemented, the information system described here should meet three basic requirements, based on the purpose of the information system:

1. *Functional:* Each user anywhere throughout the life cycle must be supplied with a sufficiently correct product life cycle overview. Since this is the intended purpose of the information system, this requirement must be met.
2. *Pragmatic:* Bear in mind that all information cannot be acquired; limitations and simplifications must be part of the design. This fact derives from chapter 4, subsection 4.4 and the facts presented there concerning data availability. If the aim is too high, the goal will not be achieved, mostly due to lack of data.
3. *User friendly:* The system must be easy to use for those involved. Any technology, tool or information intended for public or routine use must be simple and clear, since specific training cannot be given and a high level of attention cannot be guaranteed.

These three requirements must be met while bearing in mind that the environmental dimension is not central in most businesses, environmental science is a developing field, and environmental decisions need sufficiently good information now. The following design principles, formulated by the authors, should therefore help to take these limitations into account while developing an information system for environmental overview of product life cycles:

- *Be cost-effective and focus on needs*: By focusing on user needs, the information system will be relevant, easy to use and economically efficient.
- *Accept aims based on the premise that environmental issues are secondary*: Environmental issues are at best side dishes to the main courses of business and consumer decisions. So environmental information systems cannot be designed on the assumption that end users will pay them a great deal of attention.
- *Share costs by filling gaps, modular design and flexibility*: Current environmental information systems have gaps that are costly to fill. A flexible information system may be achieved by regarding data sources, expertise and tools as flexible modules.
- *Be pragmatic, enter at a low initial threshold, establish compatibility, commit to continuous improvement*: Many valuable components are already in place, with both weaknesses and limitations. User needs will be quickly met by using these ideas as a basis for a strategic approach coupled with a commitment to continuous improvement.
- *Establish individual life cycle overviews and establish knowledge maintenance*: Strategic knowledge bases and competence sources for the information system must be established and maintained.

The basis and meaning of these design principles will be presented in detail in the following five sections.

5.1.2 Be cost-effective and focus on need

An overall description of environmental information user needs is formulated in Agenda 21[441], the global action plan for sustainable development. To change actions, each decision maker will need information about environmental consequences of the intended actions. Hence, there is a direct relationship between decision makers' needs and requirements for an information system.

Figure 15[442] is a flow chart of environmental information systems produced at the Swedish national competence centre: Centre for Environmental Assessment of Product and Material systems (CPM), describing the situation of any decision maker, be it a consumer, politician, product designer, professional purchaser or corporate executive.

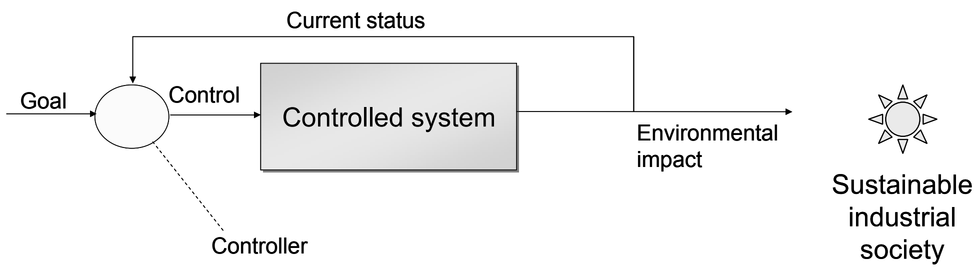

Figure 15 The flow chart shows that to navigate towards sustainable development, controllers or decision makers need to understand the system they control, and need feedback on consequences, as well as both visionary and short-term objectives. Copyright Carlson R. and Pålsson A-C, CPM, Chalmers University of Technology, 1998. Used with permission.

The diagram demonstrates that the decision maker (Controller) has an overall understanding of the meaning and the importance of sustainable development and a sustainable industrial society. This understanding is generally acquired through education, cultural acceptance, and organisational or societal policies, for example. To make decisions, the decision maker must also have sufficient knowledge about the consequences of the decision, in terms of the industrial and/or environmental aspects (controlled system) affected by the decision, and how this will impact the sustainable development of the controlled system, both in absolute terms (current status) and in relative terms (goal).

Any effective information system must meet the needs of decision situations as schematically depicted by the simple feedback model in Figure 15. Information not used for decisions leading to physical changes is thus considered uneconomical; the best economic efficiency is achieved by defining users and identifying their needs and requirements when making environmental decisions.

441 Agenda 21, http://www.un.org/esa/sustdev/documents/agenda21.

442 Copyright Carlson R. and Pålsson A-C, CPM, Chalmers University of Technology, 1998. Used with permission.

The coordination model suggested by IVL identifies three main user categories for an LCA information system: regulators, industry, and consumers[443]. The information needs elaborated in the report by KemI[444] are based on the needs of purchasers and users of chemicals. The authors of this report propose that an environmental information system for product life cycle overview should meet all user needs as described in chapter 2, and should not only focus on specific methods, such as LCA, or on specific classes of substances, such as chemicals.

5.1.3 Accept aims based on the premise that environmental issues are secondary

Environmental information may help to inform people, but environmental issues are not central in most consumer decisions or business cases. Accordingly, most decisions about physical issues do not focus on environmental concerns. This applies whether or not users are educated in environmental issues, and it impacts on the way environmental information should be presented, how it must be integrated with core business aspects, and what it may cost.

Since most people are not willing to give the matter much attention, environmental information must be presented so that it can be easily interpreted in context. For instance, many purchasing contexts do not allow for complex information from which users are intended to draw their own conclusions. Environmental information must also be relevant to the intended user, so that he feels that a decision makes a tangible difference. Most users are not willing to pay extra for, or spend extra time on, interpreting environmental information. It must be accessible and readily available, and an information system must be designed to suit different levels of ambition and different acceptable costs.

5.1.4 Share costs by filling gaps, modular design and flexibility

As documented in many of the reference reports and pointed out in chapters 2 to 4 of this report; many of the necessary components of an information system are already available, such as many primary data sources, environmental expertise, useful methods and tools, and documented user requirements. But in chapter 4 it was stressed that even though data may be generally available, the lack of actual data is discovered when requested in practice, when searching for data for specific environmental indicators such as "recyclability", "toxicity", "global warming potential" or "acidification potential".

Hence, a major weakness of current environmental information systems is that they are full of gaps that are costly to fill. But overall costs can be kept to a minimum if available resources, such as data sources are used to the full, and if resources are used to fill gaps instead of building redundant components, such as new databases or new methods and tools. Economies may also be made by harmonising environmental indicators, so that the same data sources, tools and expertise can be used for different applications by different users. It is particularly important that

[443] Naturvårdsverket (2002*), Kunskap om produkters miljöpåverkan: tillgång, behov och uppbyggnad av livscykeldata*, Swedish EPA Report 5229, pp 75-76.

[444] KemI 2004, *Information om varors innehåll av farliga kemiska ämnen.*

primary data can be used for many purposes, since they are expensive to obtain from laboratory tests, advanced modelling or scientific experts.

Available data sources, methods and tools and expertise may be regarded as individual modules of the information system, to be maintained and developed individually. Gaps may be filled by either developing new modules or using existing ones in more flexible ways. Participation and contribution may be voluntary, and if indicators are harmonised and data formats are standardised, each data source, method or tool may easily suit the needs of different users. If harmonisation and standards are introduced, this may motivate participants to benefit from increased flexibility and improved service by delivering data and information to decision makers.

One example of the great potential offered by this modular, flexible approach is the forthcoming EU REACH[445] legislation. The primary aim of REACH is to fill information gaps, where a pressing need for many experts to generate substance, property and process application data can be foreseen. If the modular, flexible approach is understood when formats for this data are being established, they will be useful for relevant methods and tools, and readily interpreted by users others than those specifically defined in REACH.

5.1.5 Be pragmatic, enter at a low initial threshold, establish compatibility, commit to continuous improvement

The IVL report proposes that an information system be based on existing LCA tools and methods[446]. By starting from available resources the initial threshold and initial costs will be low, but the first results will not provide much better information for environmental overviews of product life cycles than that which can be produced today, mainly because primary data is not available.

A pragmatic starting point based on available resources combined with a continuous improvement strategy can be used to harmonise indicators. Harmonisation and a long-term strategy may also serve as a common framework for developing formats, methods and tools to share common primary data between different tools for different applications.

5.1.6 Establish individual life cycle overviews and establish knowledge maintenance

At present it is difficult to gain a life cycle overview of most products. This is partly due to data gaps, but also a lack of common indicators. Data are available for some indicators for some products, such as greenhouse gas data on energy production and transport, and recycling data on steel, glass and paper. Even though this information is valuable, it is difficult to combine and to compare, and therefore also to use as a basis for decisions. Data availability for decision making must be improved by combining indicators for different products in meaningful ways. Data availability can be improved using practical cases that drive data acquisition for the

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[445] REACH, http://europa.eu.int/comm/environment/chemicals/reach.htm.

[446] Naturvårdsverket (2002*), Kunskap om produkters miljöpåverkan: tillgång, behov och uppbyggnad av livscykeldata*, Swedish EPA Report 5229, p 72.

purpose of decision making. For example, a case could be set up for life-cycle assessments of the same type of products over a broader range of indicators, such as energy systems, including global warming potential, recyclability, biodiversity. Another example could be a case to compare products using the same indicators, such as the impact on biodiversity of energy systems, transport systems, telecommunications, and paper as an information medium.

Coordinated cases like these could be performed as European projects, UNEP networking, sector-wise global cooperation, etc.[447], financed regionally by the EU, US or internationally by the World Bank or multinational corporations and trade associations. One initiative already in place is total life cycle data on the production of steel compiled by the steel and iron industry[448]. Similar LCA databases also exist in other sectors, such as some plastics industries and paper industries.

Results from any life cycle overview case, either from the perspective of an indicator or from that of product types, will only be valid for a limited time. Many "facts" will change as time passes, globalisation spreads, technology develops, and as resources are depleted or changed. For example, the location of resource abstraction, production management, waste management, and product design will vary, and awareness of environmental impact will change as well. So it will not suffice to have made an assessment of a product life cycle once. Knowledge will only remain valid if it is maintained; facts must be updated to mirror changes in the real world. Hence, case studies could be performed over and over again, so as to improve data availability between the cases, and the knowledge and skills for studies could at the same time be established during the projects and maintained between them.

5.2 Organisation and design

5.2.1 Introduction

Section 5.2 describes the functional design and organisation of an information system for environmental overview of product life cycles. Functional design will be presented from the overall perspective of society, i.e. from the perspective of global or regional cooperation or from that of national or local government, of business organisations, and of product design or procurement projects. Organisational design is presented from the international, regional or national viewpoint of data sources, experts and users.

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[447] Naturvårdsverket (2002), *Kunskap om produkters miljöpåverkan: tillgång, behov och uppbyggnad av livscykeldata*, Swedish EPA Report 5229, p 82.

[448] International Iron and Steel Institute (IISI) Sustainability report 2004. http://www.worldsteel.org/sustainability.php?page=report.

5.2.2 Functional design

5.2.2.1 IN A SOCIETAL PERSPECTIVE

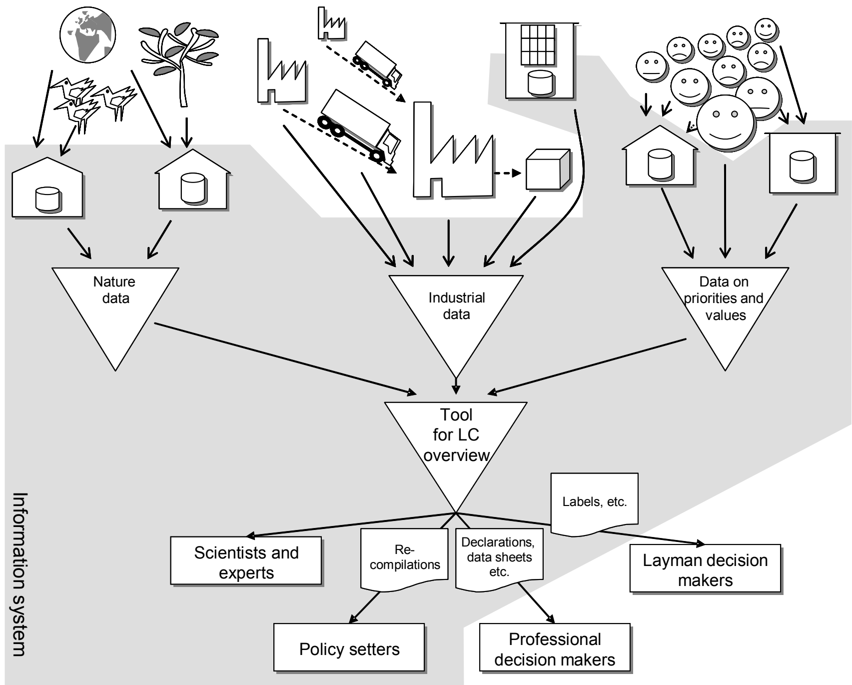

Figure 16. A simplified overview of the organisation of an information system for environmental overview of product life cycles anywhere in society.

Laymen and professional decision makers throughout society need environmental product life cycle information to make balanced environmental decisions about products (see section 1.2.1). Figure 16 shows how this information is produced from various primary data sources with the help of expertise, methods and tools (see also section 1.2.2).

The diagram reflects the fact that primary data is acquired in different places throughout society (see also section 4.2.2); For example, nature data are acquired by experts at locations all over the world, those data being compiled at different places, into statistics on sensitive species or regions, trends on resource depletion or available land areas for development. Industrial data are also acquired at different places throughout the world, by all types of businesses, government bodies and consumer organisations. These types of data are compiled into national statistics, market trends or business statistics. Data on priorities and values are collected by market analysts, NGOs and national statistical offices, for example. Methods and tools for environmental overview of product life cycles are based to varying degrees on these three types of primary data (see section 4.2.1).

Global, regional and national cooperation is needed to organise an information system as shown in Figure 16 to provide information for scientist and experts, policy makers, professional decision makers and laymen. It must be stressed that

Figure 16 is not intended to suggest that every piece of information should be directly linked to all its globally acquired environmental data. The diagram serves as a map that can be used to organise the various skills and expertise of the information system (see section 5.2.3), or together with strategies for developing resources based on gaps (compare with sections 5.1.2, 5.1.4, 5.1.5 and 5.1.6). Strategies for this process are discussed in section 5.3

5.2.2.2 FROM THE PERSPECTIVE OF BUSINESS ORGANISATIONS

A business organisation such as an industrial company or a consumer product retailer also makes use of the general environmental information system depicted in Figure 16. Any decision maker needs prepared information that relevantly combines information about the three disciplines of environmental information (section 4.2.1). However, individual information flows in a business organisation can be more well-defined than in society at large. The skills and behaviour of users are also better defined and more predictable.

Figure 17 below shows the design of a general environmental information system for a business organisation. The diagram is taken from a scientific article proposing key design elements for an integrated environmental information system for business organisations[449]. The design is theoretical, but does identify specific aspects of a practical business environmental information system:

- Defined applications i.e. the practical tasks performed by users of an environmental information system, such as documentation of significant aspects and indicators, results of measurements and sampling, statistical treatment, various types of systems analysis and aggregated systems analysis, and end-user reporting.
- Application-defined modules, i.e. the general functional modules in the information system, which may be software, data reporting forms etc.
- Application (domain)-specific conceptual model, i.e. an information system must have a conceptual model to ensure the language of the information system users is the same as that of the information system.
- Data models for storage, sharing, and communication of data, i.e. database models and data communication models[450] (shown in the diagram as the Relational data model and EXPRESS data model).
- In addition, the different modules of the information system will only work together if the information system modules have integration rules (named API - application interfaces in the diagram).

[449] Carlson, Erixon, Forsberg, Pålsson (2001), *System for Integrated Business Environmental Information Management*, Advances in Environmental Research, 5/4 pp 369-375.

[450] International Organisation for Standardisation, *ISO 10303 Product Data Representation and Exchange* (ISO 10303, known as STEP, a collection of interrelated documents forming a multi-part standard).

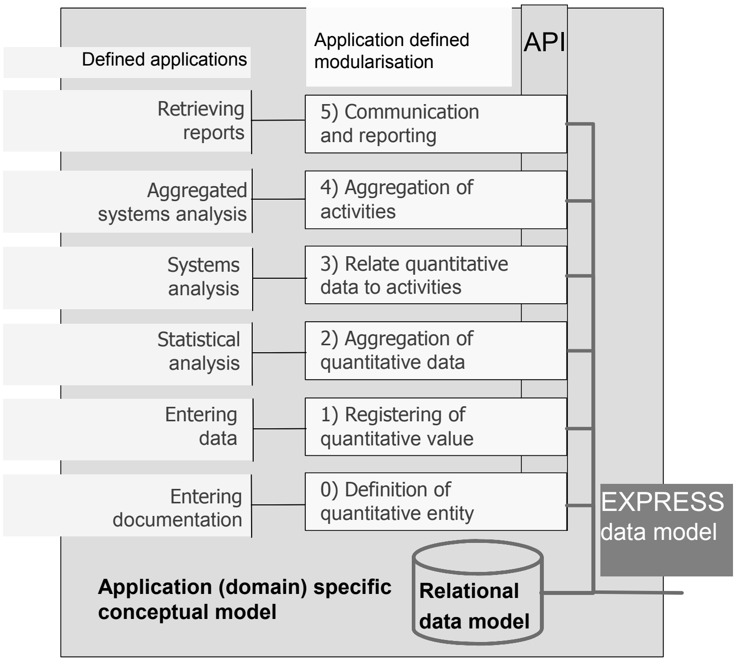

Figure 17. A technical design for developing an information system in a business organisation using, e.g. SAP/R3, IBM systems or other standard information system products.

The information system design shown in Figure 17 should be seen as either an ideal or as a product specification. It is not an overview of environmental information systems in business organisations in general.

This principal design has been tested for practical application and for implementation in industry in the IMPRESS project[451,452], as one of the projects conducted by the Swedish national competence centre: Centre for Environmental Assessment of Product and Material systems (CPM). IMPRESS includes integration of information systems for greenhouse gas emissions trading systems, information systems for operational environmental management, design for environment, environmental supply chain management, and life-cycle assessment. Expected results are partially implemented integrated information system components in industry, tested and well-described information system integration methods and tools, as well as reports describing experiences and approaches.

5.2.2.3 FROM A PROJECT OR TASK PERSPECTIVE

Businesses need environmental information in day-to-day situations where environmental issues are not central, such as during product design, procurement, or when planning major investment in new infrastructure or production units. The information must still be accurate, well-presented and focused for the task.

Figure 18 exemplifies a specific environmental information system architecture for product procurement, design, and sales. The architecture was developed in the

[451] IMPRESS - Implementation of Integrated Environmental Information Systems, viewed at: http://www.cpm.chalmers.se/html/IMPRESS.html.
[452] The IMPRESS project started in October 2004, and will end in September 2006.

European RAVEL project[453] (see Appendix 1: The RAVEL Design for Environment method). It defines the information system modules needed to support the processes from call for tenders, to product design, production, maintenance and scrapping of a rail vehicle. The design of the information system is based on general product procurement and design principles, but factors specific to the rail industry were also taken into account.

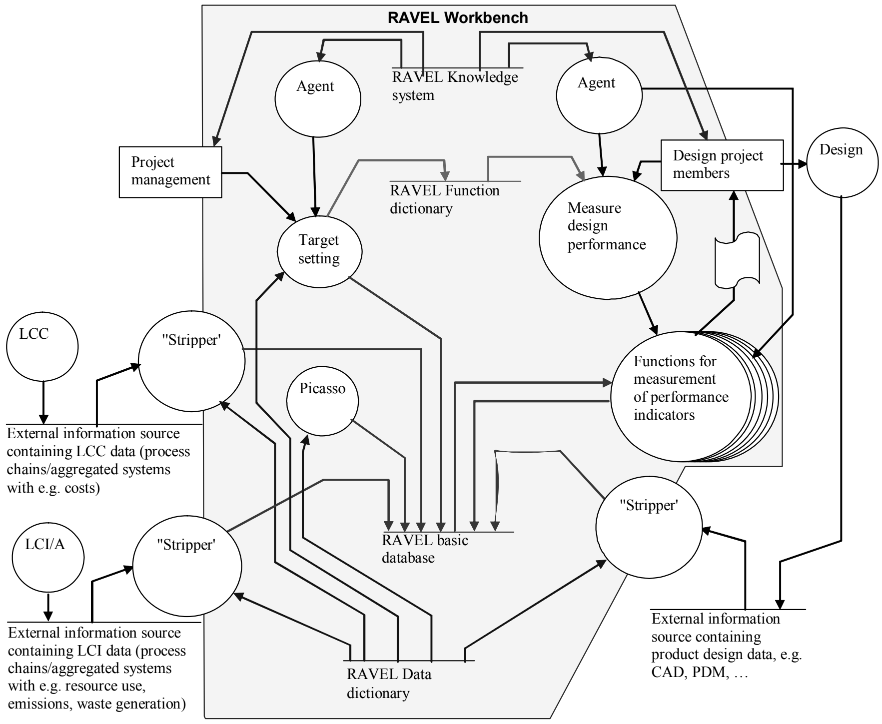

Figure 18. Overview of the scope of the RAVEL workbench.

The scope of the environmental information system for the design process, i.e. the DfE information system, includes setting target values for environmental design indicators, environmental properties of material and components, environmental design guidelines and algorithms and procedures for assessing the environmental performance of rail vehicles. The DfE information system does not include LCA tools providing results for the DfE system or PDM and CAD tools providing product structure information for assessment for the DfE information system. There are standardised methods for representing and communicating these kinds of information[454,455]. Those methods make it easier to import information into the system. All ordinary business functions surrounding the design project are also beyond the

[453] Dewulf W, Duflou J, Ander Å (2001), *Integrating Eco-Efficiency in Rail Vehicle Design*, Leuven University press.
[454] International Organisation for Standardisation (2002), ISO/TS 14048: Environmental management - Life cycle assessment – Data documentation format.
[455] International Organisation for Standardisation, ISO 10303 Product Data Representation and Exchange.

scope of the DfE system. It is designed to support, but not to interfere with or change, these processes or information flows.

The general idea is that a design project has eco-efficiency target values expressed as quantifiable design indicators. These target values are fed into the DfE information system. At any time the designer can import the full design into the information system, either in the form of a CAD drawing, as a PDM specification of materials, or as a specific information model made under DfE. The resulting design can then be assessed using the same target values and tools by anyone in the same organisation or with a similar tool, e.g. a potential customer. The idea is that this information system should be copied or otherwise made compatible with data assessment tools throughout the supply chain, so that any target values set by a procurer are transparently transposed to any supplier or sub-supplier in the entire chain (see also the example "The RAVEL Design for Environment method" in chapter 3, which describes the method in more detail).

5.2.3 Organisational design

The coordination model proposed by IVL gives industry responsibility for providing product and process data, since industry is able to produce this information in any case. It is also suggested that the government should be responsible for providing subjective information on values and priorities, for example[456]. But there are many more actors who must unite to form the organisational body of the information system. This section specifically addresses producers, vendors and publishers of methods, tools, data and information.

Methods, tools, data and information are human products, and environmental knowledge, data and information exist because experts are motivated to develop, learn and produce it. People will only be able to use it if it is made available in a usable form. And for users to consider it available when needed, it must also be easily found, readily understood and effortlessly transformed into a useful tool. This is not the case at present[457, 458] (see, e.g. section 4.4 on data availability).

The purpose of organisational design is to help users and providers of data, knowledge and information to exchange that knowledge and information, and to establish both a physical relationship through mutual awareness of each other's existence and a commercial relationship through agreements on mutual availability.

Organisational design has a substantial role in overviewing life cycles of products, since organisation of resources specifically affects their availability to users. All existing resources are made available, and all gaps are identified and can be included on the priority lists.

The resources in the organisation include environmental academics or other environmental research groups, environmental database and software vendors, and

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[456] Naturvårdsverket (2002), *Kunskap om produkters miljöpåverkan: tillgång, behov och uppbyggnad av livscykeldata*, Swedish EPA Report 5229, p 71.

[457] Erixon et al. (2003), *Data Source Inventory Report*, OMNIITOX project report, available at www.omniitox.net.

[458] Naturvårdsverket (2003), *Measuring the environmental impact of products*, Swedish EPA Report 5349.

environmental consultants who prepare databases for the various environmental methods and tools described in chapter 3 (Figure 19).

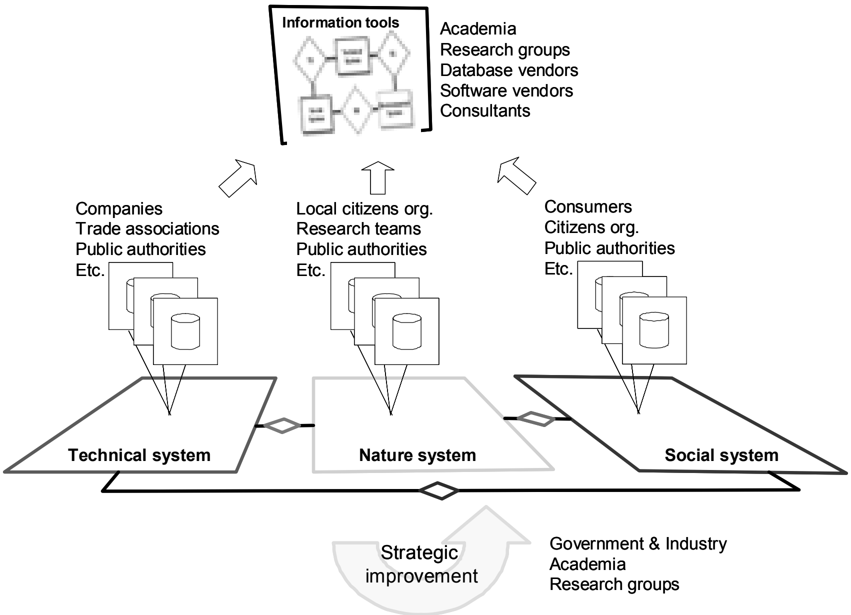

Figure 19. The organisational structure of data sources. Experts in different fields hold data from different disciplines, but all data is structured to be compatible for the users of environmental information[459].

5.3 Developing the information system

5.3.1 Strategic organisation and design

Figure 20 depicts a strategic overview of the information system presented in section 5.2.2 and Figure 16, but with the emphasis on the strategic and organisational aspects of the information system rather than its functional aspects. The information system organisation and design described in section 5.2 will not be established by a single major project, but may be the result of several projects, separated by geography, organisation and time, but with a common overall agenda. Various financiers, stakeholders and experts may agree to share that agenda to develop components, modules, standards, directives and support functions.

Figure 16 and Figure 20 both emphasise the conclusion from Table 1, i.e. that professional and lay decision makers are the most important users of the information system. But in fact, those users have little or no interest in the full concept of environmental responsibilities and sustainable development (see section 5.1.3). Their focus is on everyday life; as professionals they try to succeed in their

[459] Naturvårdsverket (2003), *Measuring the environmental impact of products*, Swedish EPA Report 5349.

business or career, and as consumers they try to live well and make ends meet. Responsibility must therefore rest with political and proactive proponents and stakeholders, to balance economic support and regulations, and to have an overview of the full range of information needs, as well as of the work done by policy makers, scientists and other experts within the information system.

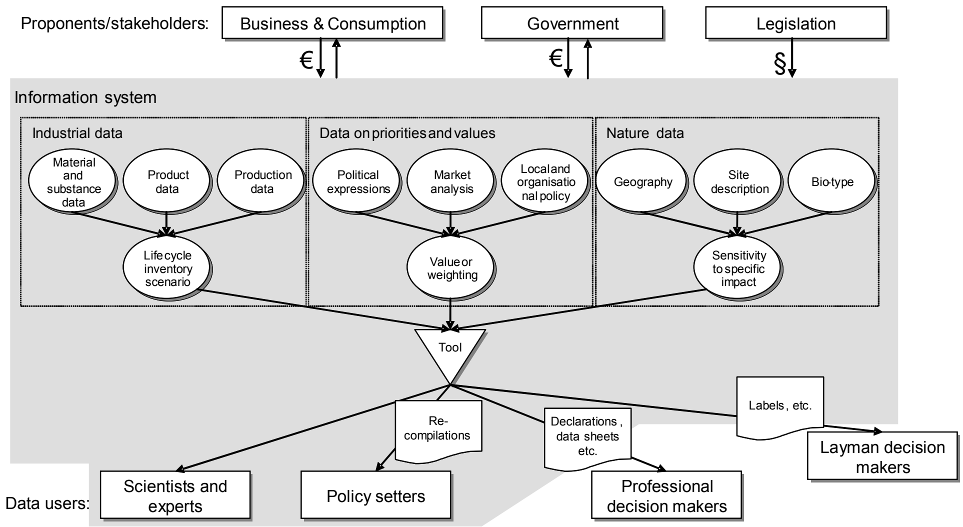

Figure 20. The strategic design of the information system.

Proponents and stakeholders in businesses and governments, at national, regional and international levels may shoulder the common responsibility for cooperating to organise data sources, expertise and other resources into a compatible network of data, knowledge and information. At any level of decisions concerning environmental information system design, this organisation should

- support and require compatibility with related information systems by addressing standards, agreements and other harmonising protocols;
- maintain an updated list of available data and data gaps, and a priority list of the missing data;
- promote development of environmental information systems that are intended to fill identified priority information gaps.

Examples of similar international agreements may be formulated under UNEP, e.g. UNEP/SETAC[460], as voluntary cooperation such as the global reporting initiative - GRI[461], or within and between industrial sectors, such as the railway industry Eco-Procurement Board[462], where both operators and manufacturers are represented to harmonise a common language and data format for communication of environmental requirements and environmental performance using environmental performance indicators.

460 UNEP/SETAC, http://www.uneptie.org/pc/sustain/lcinitiative/home.htm.
461 Global Reporting Initiative (2002), Sustainability Reporting Guidelines.
462 Railway procurement network , http://www.railway-procurement.org/default.htm.

5.3.2 Harmonisation of indicators

Section 1.2.1 outlined ways in which environmental information about a product life cycle describes how resource use, waste generation and emissions from product life-cycle processes and from the product itself impact the environment. The level of detail may range from being unspecific and qualitative to expressing quantitative values for well-defined environmental impact indicators. Examples of these indicators are presented in Appendix 3, section 3.1.5. To be able to calculate quantitative values for impact indicators, the underlying information must be appropriate. There is little chance that available data will just happen to suit the needs of relevant indicators. Long-term efforts must be made to obtain appropriate data. Primary data may be acquired and data may become available to users if appropriate indicators are communicated and harmonised. These efforts may be supported by setting individual life cycles as described in section 5.1.6, and must be made in concert at various strategic levels:

- At societal level, national environmental quality targets may serve as suggestions for choosing indicators, but they are not indicators in themselves.
- At global level, the choices of indicators may concern globally accepted environmental problems, such as those addressed by the GRI[463].
- Commonly accepted indicators for products and industries are dealt with in the various sector forums and the various systems for type I, II and III eco-labels and environmental product declarations, for example, described in chapter 3.
- Effective environmental performance indicators for product life cycles must be chosen so as to be meaningful at all stages of the life cycle.

5.3.3 Supporting development of agreements and protocols

The information system designs presented in section 5.2 and the strategic design described in section 5.3.1 are based on joint action by many cooperating compatible information system modules with different roles and at different organisational or technical levels. For example, various kinds of environmental information must be compatible for the data field level as described in chapter 4, and for databases and maintaining organisations as described in section 5.2. Developers, users and vendors of methods and tools described in chapter 3 must respond to the needs expressed by users as described in chapter 2. At the same time users of methods and tools must learn to use the same primary data for many purposes, rather than develop their own databases for each method or tool.

A common strategic agenda is required to support development of agreements and protocols at many levels throughout product life cycles. Examples are:

- Harmonised life cycle data format, as has already been initiated by the international technical specification ISO/TS 14048 Environmental management – Life cycle assessment - Data documentation format.

[463] Global Reporting Initiative, http://www.globalreporting.org.

- Harmonised formats for life-cycle impact assessment data, taking into account regional and local differences in environmental sensitivities as well as demographic differences in valuation of environmental changes.
- Harmonised formats for material and product data exchange, including nomenclatures, specifications of environmental properties etc.
- Agreements on conceptual or organisational designs of information systems, clarifying the roles of organisational partners, communication channels and data source traceability.
- Protocols at various organisational levels describing agreements on conceptual models for environmental information. This aids creation of characterisation models using laboratory data and mapping of data between industrial sectors.
- International and sector-wise protocols committed to harmonising environmental information systems wherever standards are lacking or are not considered for legal, commercial or other reasons.

There is work to be done under this strategic agenda as well. Examples of ongoing initiatives are:

- UNEP/SETAC Life Cycle Initiative[464], designed to put life-cycle thinking into practice and improve the supporting tools through better data and indicators.
- COST Action 530[465], where the aim is to bridge the gap between fundamental LCA research and the needs of industry for an operational framework and model.
- The Eco Procurement Board, presented in 5.3.1, which maintains agreements in the railway sector.
- The CASCADE[466] project, where formats for environmental data have been integrated with existing and established standards for storage and exchange of material and product data[467, 468] used in other engineering disciplines. The project also provides a way of maintaining nomenclatures at various organisational levels.

5.3.4 Establishing knowledge centres

The inter-disciplinary and inter-organisational information system designs described in chapter 5 are based on the users and user needs listed in section 2. Behind these practical demands are powerful business and political forces, such as market behaviour, responsible citizens, business competition and strategic planning. Hence, the important drivers to implement information systems throughout

464 UNEP/SETAC Life Cycle Initiative, http://www.uneptie.org/pc/sustain/lcinitiative/home.htm.
465 COST Action 530, www.empa.ch/cost530.
466 CASCADE, http://192.107.71.126/cascade.
467 International Organisation for Standardisation, ISO 15926 Integration of life-cycle data for process plants including oil and gas production facilities.
468 International Organisation for Standardisation, ISO 10303-235 Materials information for product design and validation (under development).

society are in place. But to satisfy expectations, workforces possessing suitable skills must be available.

Skills will be needed for many types of work, such as environmental monitoring for data acquisition, database maintenance, integrating information and data for decision making, technical reporting and communication and interdisciplinary software development. Long-term guidance for information system development at many levels will also be needed, such as deep technical and interdisciplinary expert guidance, as will strategic coordination and visionary guidance.

Skills of this kind require a specific inter-disciplinary and inter-organisational set-up in the interface between environmental management and data management. Some of these skills may need to be developed, but much competence already exists in the form of industrial and academic research units, educational institutions and is also possessed by commercial consultants and software or database vendors. Examples are the database managers of the European Chemicals Bureau (ECB), national Environmental Protection Agencies (EPAs), specialised research groups working in the field of environmental informatics, meeting at conferences such as the International Society for Environmental Information Sciences[469] and Informatics for Environmental Protection[470]. New skills have also been developed around the LCA databases and establishment of the Japanese LCA database at JEMAI[471], the Swiss database host EcoInvent[472] and the Swedish inter-disciplinary research group Industrial Environmental Informatics, IMI, at Chalmers University of Technology. Competence groups may be designated knowledge centres for the development of a global information system for environmental overview of product life cycles. The role of these centres is to develop, maintain and disseminate data, information and knowledge on:

- Environmental data and information, nomenclatures and statistics.
- Protocols and agreements concerning environmental databases, data communication, data sharing and data mining.
- Methods and tools, modular approaches and interfaces between information systems for environmental assessment.

Some practical benefits of knowledge centres are long-term availability, accessibility and development of knowledge on how to develop and maintain a product life-cycle overview information system and how to use environmental information and data for product life-cycle overview. The knowledge centres would also be experts in finding available data and in helping to establish new primary data sources.

469 International Society for Environmental Information Sciences, http://www.iseis.org.
470 Informatics for Environmental Protection, http://www.enviroinfo2005.org.
471 JEMAI, http://www.jemai.or.jp/english/index.cfm.
472 EcoInvent, http://www.ecoinvent.ch.

6 Recommendations and future developments

6.1 Introduction

This chapter summarises the most important recommendations for future work on the material in this report. The categories of recommendation are:

- *Purpose of the information*
  The proponents, stakeholders, purpose and users of the information must be clearly scoped.
- *Product life-cycle indicators*
  Environmental issues must be addressed jointly to achieve coordination. As in section 1.2.1, these issues are referred to as indicators.
- *Methods and tools*
  There are many methods and tools available, but most face substantial data availability gaps. It is suggested that this be resolved.
- *Data and information*
  Environmental data and data availability are complex concepts, and their structure must be understood. Focus on the users and applications for which data must be available; identify the primary data needed, structure primary data into a general format; and develop necessary data sources.
- *Information system design*
  Steps must be taken to ensure that the proponents and stakeholders of environmental information identify their mutual responsibility for an overall information system. A systematic strategy for data acquisition and management of data sources is needed, as is strategic organisation of expertise to produce simple information for end users and intermediate data aggregations.

6.2 Recommendations

6.2.1 Purpose of the information

Environmental information can be made available in many ways, but to actually improve its availability it is important to define the intended users, how the information is to be used and for what purpose.

Chapter 2 exemplifies ways of scoping and structuring the various user groups and their need for environmental information. We recommend that development of resources for environmental overview of product life cycles be based on similar structuring.

6.2.2 Product life-cycle indicators

Section 1.2.1 introduced environmental indicators to denote key environmental aspects, environmental performance indicators, environmental condition indicators, category indicators, data categories, reporting variables, etc. The aim was to illustrate that information about whole systems must be simplified. There are many ways of simplifying and creating indicators. When indicators mean the same thing to different people they can be understood, communicated, used for comparison and improvements, etc. This is one reason to harmonise indicators.

The other reason stems from the immense amount of primary data needed to produce the condensed information of an environmental product life-cycle indicator. If indicators are chosen arbitrarily with no coordination or long-term strategy, data-building capacity will not suffice to make the necessary primary data available. Data can be made available if the same primary data are requested by many users for many applications. Thus, data acquisition capacity should not be scattered; a steady data demand should be developed instead.

For these reasons, international, regional, national and sector-wise strategic coordination of development of environmental life-cycle indicators is strongly recommended. Examples can be found in section 3.2.2.

6.2.3 Methods and tools

6.2.3.1 GENERAL

Chapter 3 show that there are a large number of methods and tools available for simplifying environmental overview of product life cycles, but most of them suffer from substantial data availability gaps. Many of the methods and tools requested exist, but it is unlikely that the intended users will find the most appropriate tool on their own without substantial expert assistance. Advanced methods and tools are often developed by dedicated experts and scientists, but the daily lives of the intended users are often far from environmental concerns. It is recommended that user needs and existing methods and tools be better matched.

It is also recommended that methods and tools communicate with users and decision makers in terms of meaningful environmental indicators, and that different simplifications be made for different users, depending on their identity and task.

6.2.3.2 LIFE CYCLE ASSESSMENT

First, it should be stressed that a full LCA in accordance with the ISO 14040- series, for example, is a substantial simplification, since it both limits and structures the work required to obtain a life-cycle overview. However many process inventoried, and however many inventory parameters, impact categories or category indicators, it will still merely provide a simplified environmental product life cycle overview. This is further elaborated in section 1.2.1.

There are many ways of simplifying performance of a life cycle assessment, ranging from general LCI databases, simple full LCA software, prefabricated cradle-to-gate and end-of-life databases for specific product types, use of available statistics by I/O-analysis, communication through EPD systems, simplified screening LCAs, etc. Further simplifications have been made by the RAVEL method (described in section 3.3.1.2.1), for example, where none of the performance of the LCA is evident to the user; it merely appears as environmental product life-cycle indicators, easy to use and easy to understand for the decision maker.

It is recommended that the meaning of simplified life cycle assessment or simplified environmental overview product life cycles be discussed systematically. There are many simplifications to be made regarding data acquisition, level of detail, communication of results, use of results, or tools for making complex LCAs. Hence, "simplified LCA" is too vague a concept.

It is recommended that the use of harmonised environmental product life cycle indicators be distinguished from discussion of LCA methodology and tools. Policy makers, scientists, professional decision makers and other stakeholders and proponents must cooperate to develop methodologically correct, feasible, simple, meaningful and understandable indicators. When the indicators are defined, experts and others should not need to be bothered with methodological issues, but should be able to assume that information and practice are credible, transparent and compatible, internationally, between industrial sectors and product categories and independently of decision contexts. The RAVEL methodology, based on screening LCA or I/O analysis and a continuous improvement strategy, in combination with EPD systems, may be the most feasible approach.

6.2.4 Data and information

The most crucial practical problem with data is *availability:* to have the right data when it is needed. This report addresses this problem by showing how many users and applications can make use of the same data, the common primary data. Section 4.4.1 thoroughly defines data availability, based on the fact that many practical properties of data must be considered before it can be decided whether data actually exist for a given purpose. At present there is no consistent strategy for achieving full data availability.

From the layout of this report it may be understood that there are four aspects to be considered in establishing common primary data for environmental overview of product life cycles:

1. Focus on the users and applications to make data available for (see section 6.2.1). It is impossible to provide a general solution.
2. Identify the primary data needed to produce the information requested by the intended users and applications. This was done in chapter 3.
3. Arrange the identified primary data in a general format so that all the methods and tools can share the same primary data sources. See section 4.3 and Appendix 2.
4. Establish a strategic build-up of all necessary primary data, which must be based on well-defined environmental product life-cycle indicators.

It is recommended that long-term decisions be taken to resolve data availability issues for a number of environmental product life-cycle indicators significant for the global, regional and local environment anywhere in the world, and for sustainability for future generations. These long-term environmental indicators should be determined at various strategic levels, such as the UN and World Bank, by the USA, EU and other regional unions of countries and states, at national level, in industrial sectors and in public procurement and consumption. Indicators should be set to serve as long-term targets to drive action plans towards improved data availability. Cooperation should be established and expertise should be made available to support synergetic definitions of indicators, so that primary data sources and expertise serve as many purposes and applications as possible.

Since most primary environmental data sources are established on ad hoc principles for specific purposes with little or no information system contexts, most data sources are incompatible at all levels, technically, conceptually and semantically. It is recommended that international standardisation efforts be supported, so that concepts, terms, common data formats and nomenclatures can be designed to integrate data and information in different systems.

6.2.5 Information system design

Resources and tasks must be organised to establish systematic and rational acquisition of information for environmental overview of product life cycles. Information about actual or modelled upstream and downstream processes must be measured, acquired, collated and communicated. The same is true about knowledge in the form of facts or expert models on environmental impact, as well as data on priorities and other value judgments made by policy makers and decision makers. The organisation of information handling in this way is termed an "information system" in section 1.2.2.

Chapter 5 of this report recommends that international, regional and national cooperation be established to implement the information system by practical efforts such as coordination of competence and support of harmonisation and standards. It is also recommended that these efforts be established as a long-term strategy, and that competence capacity be developed by knowledge centres, for example (section 5.3.4) and data generators and maintainers. This dedicated capacity should be assigned to support and work with companies, consultants and software vendors to establish international, sector-independent and interdisciplinary coordination. A combination of business models and responsibilities should focus on supplying environmental information to decision-makers throughout product life cycles.

Comprehensive strategies of this kind cannot be established without clear visions and policy decisions by governmental, industrial and non-governmental leaders. It is therefore strongly recommended that environmental information proponents and stakeholders shoulder this mutual responsibility for an overall environmental information system (section 5.3.1 and Figure 20).

6.3 First steps to data availability for environmental overview of product life cycles

6.3.1 Introduction

In this section the authors recommend the steps to be taken to improve data availability for environmental overview of product life cycles by establishing common primary data. These recommendations are considered feasible and essential, but may be adopted in an order other than that proposed here. It is also intended that they be taken "iteratively", i.e. incrementally, so that during each new "iteration" the strategic level is elevated, increased knowledge is generated, geographical dissemination is improved, and different parts of society are permeated. It is also expected that the absolute mandate of the board may increase over time, with appropriately moderate mandates during the first iterations. A natural starting point is limited pilot projects in given sectors, or at national or regional levels.

6.3.2 Step 1: policy and competence

The first step is to appoint policy makers, a responsible board and the competence base.

6.3.2.1 COLLABORATIVE BOARD

Set up a collaborative board (or network or association) of proponents and stakeholders (see section 5.3.1) in order to develop rational information systems. The board should be willing to take charge and create visions and strategies. The board should establish an information feedback relationship with both professional and lay decision makers.

The board could play a key role in prioritising between tasks, maintaining the strategy, and establishing and securing long-term funding through relations with funding financing institutions and banks. It could also establish, pursue and maintain necessary standards.

The long-term goal of the board should be to establish and maintain international collaboration between EPAs, the boards of multinational corporations and the academic elite in related fields. The strategy of the board should be to carry out inter-organisational programmes of practical and well-defined problem-solving/gap-bridging projects e.g. defining a specific indicator, exporting a specific database to common formats, starting a database of specific primary data. The board should also distinguish research from implementation by delegating implementation responsibilities to economically sustainable and sound businesses. Research issues must be quickly identified and presented to a strategic academic reference group. Research funding within this domain must be based on problem solving.

There are similarities between the UNEP/SETAC LC Initiative, for example, and this collaborative board, but the differences are that this board

- focuses on simple information for environmental overview of product life cycles for end users, regardless of whether LCA is the method or not;
- considers providing simple information for end users as the primary objective and methods and tools as secondary, while the UNEP/SETAC LC Initiative has emerged from the methodological point of view adopted by the method developers;
- stresses primary data as the basis for all other information. Acquisition and availability of primary data is not part of the UNEP/SETAC LC Initiative, only highly aggregated LCA data and databases.

In the first place, the work should be carried out within the framework of existing organisations, such as the EU:s Joint Research Center and ISO, where already similar activities are ongoing. Such a development can complement existing LCA format developed within ISO (ISO/TS 14048), with formats for substance-, material- and component data and data on environmental impact of chemicals in different geographical areas, but also through working for using the same data format different applications in different societal and industrial sectors.

6.3.2.2 KNOWLEDGE CENTRES
Establish knowledge centres (see section 5.3.4) around existing competence units, selected on criteria such as experience, practical value of the specific competence, potential to grow in the direction of strategic needs. International cooperation and competence sharing between knowledge centres should be promoted to add impetus to the harmonisation processes as well as the sharing of competence and experience.

6.3.3 Step 2: scope and format

The collaborative board should define scope in terms of the users to address, the applications to consider and the indicators to use to describe environmental overview of product life cycles. On the basis of these decisions, a common data format can be developed for exchange of data between data sources and methods and tools. The format may be developed by designated experts at the knowledge centres, and should be developed jointly with tools developers and data source maintainers. The data format should

- suit all the primary data needed by the intended users;
- be based on a general level of primary data as described in sections 4.1 and 4.3 and in Appendix 3;
- allow for relevant documentation;
- be non-redundant, i.e. economical and effective.

6.3.4 Step 3: infrastructure and information system

On the basis of the selected and defined indicators, develop the use of the common format to establish infrastructures and communication channels to share data from sources to (first) professional and (then) lay decision makers. This includes much practical cooperation between data source maintainers, tools developers and informatics experts.

The data source maintainers should be supported as necessary, to provide the necessary primary data and to establish publication procedures. Skills for aggregating primary data into layers of semi-simple data should also be valuable. These are possessed by risk analysts, ecologists, LCA consultants, etc. It should also be necessary to find ways of motivating providers of other information, methods and tools, as well as experts in relevant fields, such as policy makers, data publishers and software developers, to develop PSRs, product design criteria, eco-procurement criteria etc.

The result should be a complete mapping of the information system, similar to Figure 16, for a specific category of users, a specific application and a specific indicator. Each component or module is recognised and each gap is identified.

6.3.5 Step 4: generate new data and maintain knowledge

Section 5.1.6 described how life cycle overviews may be achieved. On the basis of the new knowledge, experience and policies acquired in steps 2 and 3, the information system may be widened and the knowledge will need to be maintained.

The board should identify international industries, countries and financiers willing to complete and also maintain such full life cycle overviews, in order to acquire and establish improved data availability and improved knowledge.

6.3.6 Step 5 and ahead

The board should revisit areas in need of improvement and focus on deleting a few priority obstacles at a time. The board should allow short time frames for project completion and constantly assess whether success has been achieved. Flexibility, a pragmatic approach and practical achievements are the basis for the success of the board, combined with cooperation, consensus and coordination.

Thus, establishment of common primary data for environmental overview of product life cycles is a practical process, which can be achieved with determination and continuous improvement.

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1 Appendix: Examples of data handling in methods and tools for environmental assessment

Example 1: The RAVEL Design for Environment method

The RAVEL[1] method is a design for environment (DfE) method aimed at improving the eco-efficiency of products. The method allows measurement of environmental performance in the design phase and also communication of environmental performance within a supply chain.

The method is based on Environmental Performance Indicators (EPIs), a common material list and material property data for each material in the list. A set of EPIs is used to communicate requirements and target values governing the environmental performance of the product to the designer. Actual performance is then measured and communicated back; see Figure 1 below.

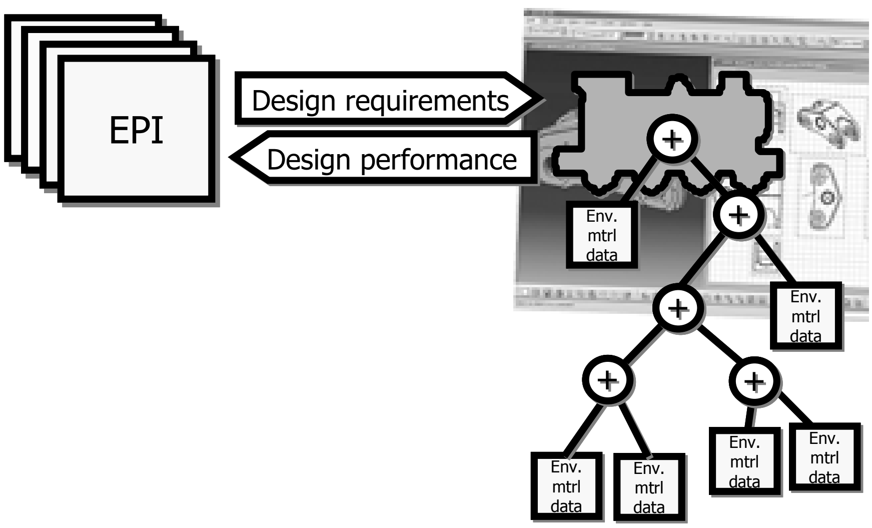

Figure 1. EPIs for communication of environmental performance of products.

The method has been developed and implemented in the European railway industry in the RAVEL and REPID projects, but applies generally to any manufacturing sector.

According to this DfE method as described below, the process consists of an implementation phase and an execution phase.[2]

Implementation of the method

Define a set of Environmental Performance Indicators (EPIs)

This method requires that a set of common EPIs be explicitly defined on the basis of regulations, company policy etc. The term "Environmental Performance Indicators" (EPIs) is an extension of the definition in ISO 14031. EPIs are quantitative expressions of the environmental performance of the product to be checked. Each indicator must be explicitly defined either per sector or per company. Algorithms to calculate each indicator must be agreed and documented. This set of indicators will reflect the requirements to be met by the product and also measure its environmental impact.

The criteria for EPIs used in a DfE-system can be summarised as follows.

- They must be measurable.
- They must be able to control and be influenced by the DfE process.
- They must address important and well-defined environmental issues.
- They must be easy to understand.
- They must be understood and agreed on by all stakeholders.

A definition of an EPI consists of a detailed description, algorithms and defined inputs and outputs. The process of deciding EPIs for product design can be divided into 6 steps:

1. Identify a common environmental policy shared by the company and its key stakeholders and customers/markets.
2. Identify the conclusions and consequences to be drawn from the policy.
3. Assess the product, using LCA, to identify the properties and parameters that may be subject to specific design indicators, e.g. alternative materials, alternative suppliers, separation of materials to allow more energy-efficient disposal.
4. Estimate the scope for acquiring data for the key design parameters.
5. Rework the definition of each design EPI on the final selection list so that it can be easily understood by anyone in the design process, by the salespeople and by the customers.
6. Use, evaluate and improve the list of EPIs.

Calculation of EPIs is based on common material property data. Hence, defining EPIs also involves defining the material properties to be acquired. The definition of other aspects of the EPI definitions, such as how to calculate weight, or the definition of energy use, must also be agreed on.

Develop a material list

All users of the DfE system must use the same or compatible material lists, since calculation of the EPIs is based on the properties of those materials. If many parties use the system, they all need either to agree on a common list or establish a translation system between the lists. A common material list consists of construction materials used in the industry. If incompatible material lists are used by different parts of the system, the results of the calculations will not be comparable.

Acquire environmental data needed to calculate the EPIs

Material data needed to calculate the EPIs must then be gathered, documented and inserted in a common database. This should be done systematically, including collection and examination of available information sources, finding the right data according to the material property definition and data quality requirements, documenting the data, and finally reviewing it. Use of a common format, such as the ISO/TS 14048 Data documentation format, is highly recommended.

Implement calculation functionality for the defined EPIs

To calculate the EPIs, the algorithms defined earlier must be implemented as calculation functionality. Calculation of the material-related indicators is based on properties of the materials in the analysed product. Calculation functionality aggregates the commonly defined properties for those materials, in accordance with the algorithms, into a score for each indicator. An indicator can be calculated for any part in the component structure; see illustration of calculation procedure in Figure 2.

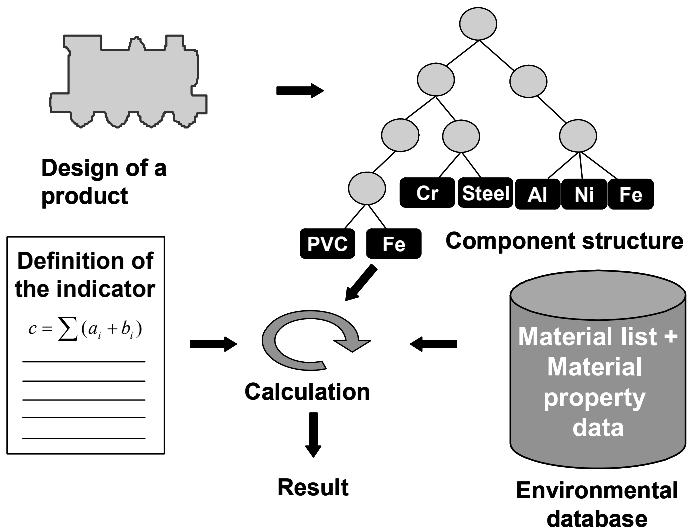

Figure 2. Calculations of EPIs.[3]

Execution of the method

Specification of environmental requirements

The following steps are performed by an environmental coordinator, for example, using a tool (e.g. a spreadsheet) where the environmental requirements and targets are defined for the product in terms of the defined EPIs agreed on earlier.

- *Create a DfE project with an environmental policy*
  Create a project that will keep all information on environmental requirements (selection of EPIs and definition of target values for each selected EPI) in the product together.
- *Choose Environmental Performance Indicators (EPIs)*
  A set of EPIs for a given product is chosen from the defined list. The chosen EPIs should cover the whole life cycle of the product and have the same calculation basis.
- *Set target values for the EPIs*
  Target values for the chosen indicators should be set to meet project requirements.

Verify that a product design fulfils the requirements

The following steps are performed in the product development process to verify that a product design meets the requirements specified in the previous step. An easy-to-use tool is needed to analyse the environmental performance of products in terms of the defined EPIs based on the common material list, material property data for each material in the list, and calculation functionality for each EPI.

- *Insert product structure*
  Insert data on the product structure including details of the materials and components the product is made of, and also other required information as specified in the EPI definitions. The materials must be selected from (or translated to) the common material list. To reduce the amount of work, the product structure should be imported from other systems in which it already has been inserted, such as a CAD or PDM system.
- *Calculate environmental performance indicators*
  Calculate the indicators for the product using the calculation functionality defined earlier. The calculations are based on the material list and the material properties relating to these materials.
- *Improve or communicate the result and use it for decision making*
  Compare the calculated EPI values with the targets. If the product fails to meet target, redesign and recalculate to see if the target is achieved. This can be done repeatedly in engineering design until all targets are met. The calculated EPI values can also be used to compare alternative designs to see which one is best from an environmental point of view. In addition, reports can be generated with information about indicator results, definitions of the indicators and how the calculations were performed.

For complex products such as rail vehicles, indicators can be calculated per part in the product structure to find out where the hot-spots are and where to concentrate to improve environmental performance. One set of targets can focus on product level and other targets on specific sub-components of the product.

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[1] Dewulf W, Duflou J, Ander Å (2001), *Integrating Eco-Efficiency in Rail Vehicle Design*, Leuven University press.
[2] Erlandsson, Flemström, *Information material for REPID software session,* Industrial Environmental Informatics, Chalmers University of Technology, 2003.
[3] Carlson R, Erlandsson M, Flemström K (2004) *Standards and tools for environmental design and supply chain management in the railway industry*, Industrial Environmental Informatics, Chalmers University of Technology, Sixth International Conference on EcoBalance, Japan.

Example 2: Policy-controlled environmental management

Background

The "Policy-controlled environmental management" project was carried out between 2002 and 2004 at the CPM competence centre, hosted by Chalmers University of technology. The project developed a method for policy-controlled environmental management. The process comprises eight steps, as may be seen in Figure 1 below.

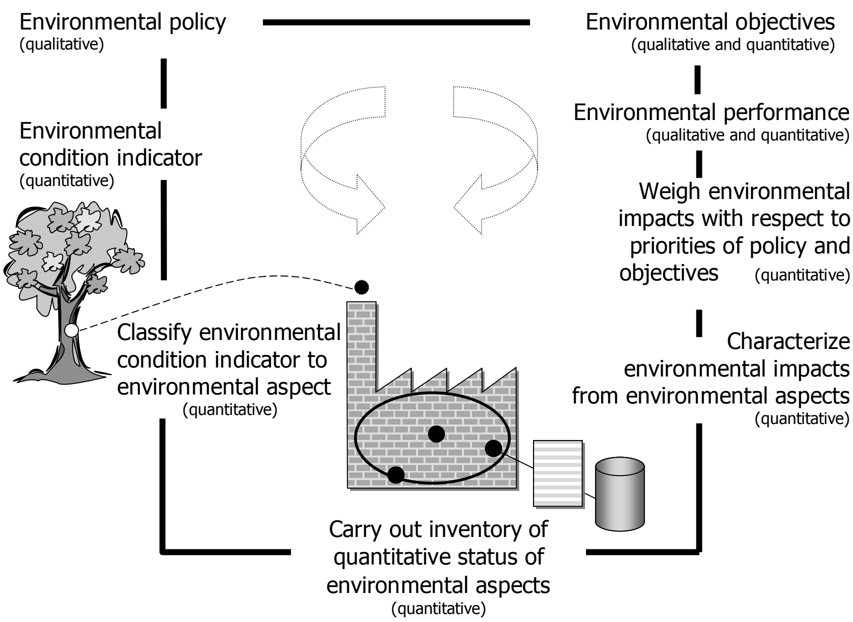

Figure 1: A company's environmental performance is measured in terms of impact on a set of environmental condition indicators. A conceptual analysis is made of the environmental policy to find the relevant environmental condition indicators. The company's key environmental aspects are identified from the selected set of indicators. The environmental objectives are based on environmental performance and show whether the policy needs to be updated. © Carlson, Häggström, Pålsson, Chalmers University of Technology, 2004

The company's environmental performance is measured in terms of impact on a set of environmental condition indicators. A conceptual analysis is made of its environmental policy to find the relevant environmental condition indicators. The impact on the indicators of the company's environmental aspects is calculated using quantitative cause-effect models. These have been borrowed from LCA methodology, where they are called characterisation models.

The project consisted of a pre-study, a problem inventory and workshops involving participants from industry and the academic world. This has allowed language to develop so that terms and concepts have been understood in both worlds. A prototype software tool has also been developed to support the method.

Method

Environmental policy

The environmental policy is formulated. The choice of how to express or indicate environmental impact is subjective and depends on the viewpoint of the observer. This viewpoint may be expressed as a "principle" - the "impact indication principle". Companies express their impact indication principles in their environmental policy.

The policy should be formulated operationally. The company can develop an external policy and an internal one that is more operational, or use other supplementary documents, e.g. guidelines or strategies to provide operational support.

Environmental condition indicator

A conceptual analysis is made of the policy to find the company's established responsibilities. The environmental condition indicators are extracted as the consequences of the policy statements. Indicators that are quantitative and relevant measures of the state of the environment are chosen. This can be done transparently if it is documented, e.g. by underlining phrases in the policy that identify specific indicators and explaining the choices and interpretations made.

If possible, the next step will be simplified if the environmental condition indicators are chosen from the indicators used by existing impact assessment methods that have documentation and ready-made characterisation methods. But this choice does mean the environmental impact assessment method will have to be interpreted to ensure that the values in the method accord with the company's general policy.

Classify environmental condition indicator to environmental aspect

The effect on the environmental condition indicators of the environmental aspects at the company is examined. This step is compatible with the classification step in the ISO 14042 standard. Characterisation models are cause-effect models that can be used to find links between indicators and aspects. They are generally very expensive to develop, and existing models such as EPS 2000, Eco Indicator 99 and EDIP can be used if the indicators of the method are interpreted in a similar way to the company’s environmental condition indicators. Environmental aspects are assigned to one or more environmental condition indicators.

Make an inventory of the quantitative status of environmental aspects

This step involves acquisition, processing and reporting of numerical environmental data for the production plant, business unit or entire company, and also modelling of the production system based on the environmental aspects of interest. This corresponds to the environmental review and the general measuring and monitoring under ISO 14001. This part of the method has not been developed in the project. The result of a previous CPM project, the CPM/SSVL method[1], was considered sufficient to meet the needs.

Aspects not covered by the policy but still needed owing to laws and regulations, customer demands, etc. must be added to the list of aspects. The result is a list with all the environmental aspects of the company and a quantitative value for them.

Characterise the impacts of environmental aspects

This step involves selecting or developing characterisation factors for all relationships between aspects and indicators. Characterisation factors are obtained using a characterisation method. This generally leads to a paradoxical problem: existing methods are judged too ill-suited to the company, but it is too expensive to consult environmental experts and create new ones. A compromise might be to start by using a ready-made method, while having the in-house expertise to adapt it to the company in a transparent way. Thus, the characterisation options are to:

- Develop new characterisation methods from scratch.
- Adapt existing characterisation methods.
- Use existing characterisation methods as they are.

The last alternative can only be used if the environmental condition indicators are chosen from an existing method. The characterisation factors are used in the calculations that are performed in the step "Environmental performance".

Weigh up environmental impacts in relation to priorities of policy and objectives

This step involves setting priorities by selecting or developing a prioritisation method. Prioritisation is a subjective ranking of the (adverse) environmental impacts of the company's activities. The prioritisation method must be based on the policy and can be used both to decide priorities between environmental condition indicators and to identify key environmental aspects. The company can develop company-specific priorities or use ready-made weighting methods.

Priorities can be decided in a less person-dependent way if this is done by an interdisciplinary panel; this method was therefore chosen in the project. The alternatives to a panel procedure include using some kind of checklist, having an environmental expert decide priorities or using the weighting methods employed by EPS 2000, EDIP and Eco-indicator 99. However, the impact indication principles of such ready-made prioritisation methods will probably differ from the company's environmental policy.

Environmental performance

The current status of the company's environmental performance is measured in terms of impact on the environmental condition indicators. The characterisation and prioritisation methods from the previous steps are used to calculate the impact on the environmental condition indicators of the company's operations.

Further information that can be obtained from the calculations includes:

- The company's key environmental aspects.
- The products having the most detrimental environmental impact.
- The company's environmental performance compared with previous years.

Environmental objectives

The environmental performances of each unit are communicated and aggregated. The objectives are set at company level to prevent individual units from setting objectives that will sub-optimise the environmental performance of the company as a whole.

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[1] The CPM/SSVL methodology is based on PHASETS [Carlson R, Pålsson A-C (2001): "Industrial environmental information management for technical systems", Journal of Cleaner Production, 9 (5): 429-435, Elsevier Science Ltd] and SPINE [Carlson R, Löfgren G, Steen B (1995): "SPINE – A Relational Database Structure for Life Cycle Assessment", Report B1227, Swedish Environmental Research Institute, Gothenburg].

Example 3: Performing LCA

An outline is given below of how LCA is performed according to the ISO 14040 standards.

The ISO 14040 series

The framework and principles are described in ISO14040:1997. According to ISO 14040, an LCA comprises four incremental phases:

- Goal and scope definition (described in ISO 14041:1998)
- Inventory analysis (described in ISO 14041:1998)
- Life cycle impact assessment (described in ISO 14042:2000)
- Life cycle interpretation (described in ISO 14043:2000)

ISO 14040 also describes reporting and critical review of the results.
ISO/TS 14048:2002 describes the data documentation format.

Goal and scope definition

ISO 14041 states that goal and scope must be consistent with the intended application of the LCA. The LCA begins with the definition of the goal and scope, but since LCA is generally an incremental process, they can be refined later on, based on interpretation of the results throughout the study.

To better reflect the intended application, processes and flows originally excluded from the system studied can be included later on inside the *system boundaries* and vice versa. The time frame or the impact categories selected may also need to be refined when more information is available.

Inventory analysis

ISO 14041 also describes the inventory analysis: how to define the product system that performs a function, and how to collect and handle data. The result of the inventory analysis is the life cycle inventory (LCI), a "list" of all relevant inputs and outputs from the system studied. These inputs and outputs are called LCI data will later be linked to their environmental consequences in the impact assessment phase of the LCA. Energy inputs can also be materialised if traced back to the energy source e.g. coal, oil or uranium.

The reliability of the results of the LCA study depends very much on the reliability of the data from which the results derive, and data documentation is therefore a key issue.

Inventory components

A *product system* is a collection of unit processes connected by intermediate flows. A product system can perform one or more functions.

The *unit process* is the smallest portion of a product system for which data is collected. Examples are individual production processes, production lines, cradle-to-gate systems for components and transport.

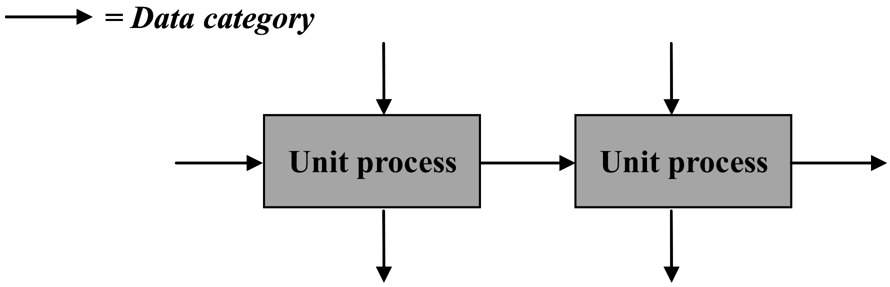

Figure 1. Data categories (or inputs and outputs) of unit processes.

Data categories are specifications of the quantified inputs and outputs of a unit process or product system. The choice of these varies depending on the goal and scope of the study. Examples are resources, products, energy, raw materials, emissions and waste.

Data collection and documentation

Data collection is usually the most resource-intensive part of the LCA. Documentation of data collection will assure the quality of the results and may also mean that the collected data can be reused. A common data documentation format enables the collected data to be understood, interpreted and reviewed. It will also aid the exchange, storage and retrieval of LCA data without loss of transparency.

Data quality is needed for the data to be useful and reliable. The reliability of the results of the LCA study depends very much on the reliability of the data from which the results derive.

Data quality may be defined as "characteristics of data affecting their ability to meet stated requirements". The quality of a data set can only be assessed if the characteristics of the data are sufficiently documented. Data quality therefore corresponds in many respects to documentation quality.

Life-cycle impact assessment

ISO 14042 describes how to assess the environmental impact of a product system from a chosen environmental perspective. All inputs and outputs surveyed are related to their environmental consequences as illustrated below:

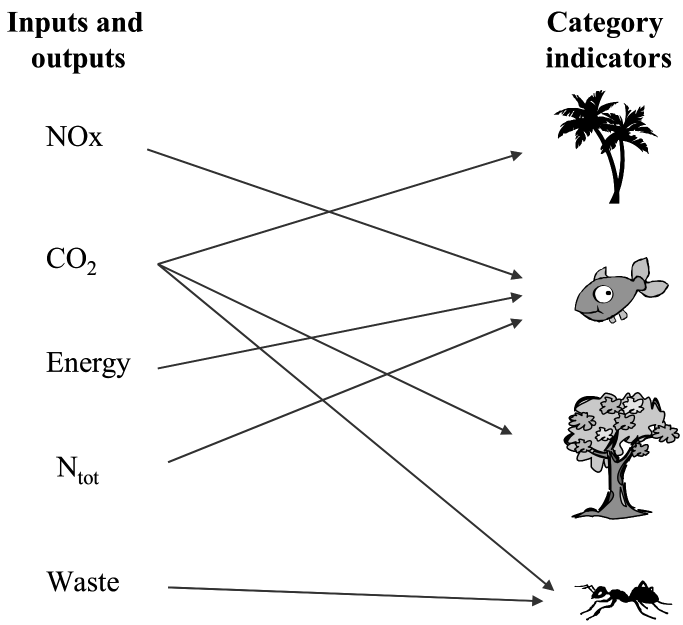

Figure 2. Relating inputs and outputs to environmental impact.

The quantitative impact on each category indicator is calculated. The result is an LCIA profile that may optionally be further treated by normalisation, grouping and/or weighting.

Mandatory elements

- Selection of the relevant impact categories, category indicators and characterisation models.
- Assignment of the LCI results (classification).
- Calculation of the category indicator results (characterisation).

Optional elements

- Normalisation - calculation of the relative magnitude of the LCIA results from a comparison with reference information.
- Grouping - assignment of impact categories to different groups, e.g. use of resources and emissions or global regional and local spatial scales.
- Weighting - converting the results of each impact category into a comparable unit with value-based numerical factors or simply "weighting factors".
- Data quality analysis.

Impact assessment methods

In practice, impact categories, category indicators and characterisation models are selected by the choice of impact assessment method, e.g. EPS, EDIP, and Eco-Indicator ’99. EPS is a Swedish method where the weighting model is based on surveys and interviews with people in the OECD countries about their willingness to pay (WTP) to avoid certain environmental impacts. EDIP is a Danish method in which the weighting model is based on the distance to political targets. The weighting factors of Eco Indicator ’99 are based on decisions by an expert panel.

Life cycle interpretation

ISO 14043 describes how to prepare for reporting conclusions and recommendation from the study. The findings of the inventory analysis and the impact assessment are combined in the interpretation in a way consistent with the defined goal and scope so as to reach conclusions and recommendations. The completeness, sensitivity and consistency of the study are checked. This is done interactively with the other phases of the LCA. There are three key elements in the interpretation:

- Identification of significant issues based on the results of the LCI and LCIA phases of LCA. This is performed by identifying and structuring information and identifying key issues.
- Evaluation, in which checks are made to ascertain completeness, sensitivity, consistency and other issues.
- Conclusions, recommendations and reporting.

Reporting

Reporting is an important part of an LCA study. Some key issues:

- Results of the LCA are reported to the intended audience.
- Type and format of the report are defined in the scope.
- Results, data, methods, assumptions and limitations must be transparent and presented in sufficient detail in the report.
- Use of results and interpretation must be consistent with the goal and scope.

Critical review

Critical review is performed to ensure that:

- The LCA methods used are consistent with the standards.
- The LCA methods used are scientifically and technically valid.
- The data used are appropriate and reasonable in relation to the goal of the study.
- The interpretations reflect identified limitations and the goal of the study.
- The study report is transparent and consistent.

The scope and type of critical review are defined in the scope phase of the LCA. Where the study is used to support a comparative assertion that is disclosed to the public, a critical review is required to reduce the likelihood of misunderstandings or adverse effects on external stakeholders. However, the critical review must not be seen as a confirmation of the interpretations in the comparative assertion.

[1] Carlson R, Häggström S, Pålsson A-C (2003), *LCA course for users of LCA data and results*, Report for the CASCADE Project, available at http://192.107.71.126/cascade/.

Example 4: Input - Output Analysis

Background

An Input-Output Analysis (IOA) is based on input-output (IO) tables which are a part of the national accounts and statistics. These tables describe how products are sold by producers and bought by either consumers or producers in other sectors. Input-output analysis was developed by Wassily Leontief in the 1930s, as an economic instrument at societal level. Since then IOA has been applied to many economic problems. According to Leontief, there is a connection between all sectors, which is captured in the economic system[1]. In an environmentally expanded IOA, these connections between economic activities are translated into environmental impacts caused by the various sectors. For example, the manufacture of cars worth SEK 1 million requires steel, plastics and electricity to be produced at a certain cost. These identified production costs can be linked to the environmental impacts associated with the sectors producing steel, plastics, electricity etc. An overview of the total environmental impact of producing cars worth SEK 1 million can be achieved by aggregating these environmental impacts caused in different sectors [2]. For instance, IOA can be used to gain an overview of the environmental impact caused by various product categories used in a country, a region, a company, an organisation etc. IOA can also be used to monitor the environmental impact caused by manufacturing a specific product or using a specific service.

An IOA is based on some assumptions, such as linear relationships between inputs and outputs. Increasing the output of goods and services from any sector requires a proportional increase in each input from all other sectors. Emissions are also assumed to be in linear proportion to the production volume of each sector. Consequently, a production volume of SEK 100 million generates emissions 10 times greater than those caused by a production volume of SEK 10 million. Moreover, IOA is static, and thus refers to a certain period[3].

Method

The standard assessment performed using IOA is the calculation of energy use and indirect emissions from various sectors relating to final use in a given system, or end use of a certain product. The production needed for either the actual end use or notional end use of SEK 1 million, for example, is calculated. This section provides an overview of how these assessments are performed:

1. Identify relevant IO tables, which contain data on products sold by producers, either for end use or as an input in further manufacture in other sectors. In Sweden these national account statistics are provided by Statistics Sweden[4].

Table 1. An illustration of a simplified input - output table for three sectors. The rows contain the total sales from each supply sector; the columns contain the required input into each production sector and the final demand. The figures shown are presented as an example only (not real data). All figures are in SEK millions.

Input to: / Supplied from:	Sector A	Sector B	Sector C	Final demand	Total output
Sector A	0	10,000	13,000	7,000	30,000
Sector B	4,000	0	2,000	9,000	15,000
Sector C	10,000	4,000	0	11,000	25,000
Value added	16,000	1,000	10,000		
Total input	30,000	15,000	25,000		

2. Normalise the columns in Table 1 to achieve the input - output coefficient table (Table 2). This table includes information that one unit of output from sector B requires 0.67 units of output from sector A, 0.27 units of output from sector C, and generates 0.6 units of value added.

Table 2. Input - output coefficient table for the input - output table (Table 1). The columns show how much input is needed to produce each unit of output.

	Sector A	Sector B	Sector C
Sector A	0.00	0.67	0.52
Sector B	0.13	0.00	0.08
Sector C	0.33	0.27	0.00
Value added	0.54	0.06	0.40
Total	*1,00*	*1.00*	*1.00*

3. Identify data on the quantity of emissions and energy use by each sector using System of Environmental and Economic Accounts (SEEA), which is a satellite system to the national accounts. In Sweden this data is supplied by Statistics Sweden.

Table 3. An illustration of environmental data in SEEA describing the quantity of emissions and energy use in various sectors.

	Emission: (tonnes)				Resources:	
Sector:	CO2	SO2	NOX	…	Consumption of electricity and district heating (PJ)	…
Sector A	23,00	1.17	22.32		6	
Sector B	83	0.34	12.80		10	
Sector C	42	4.89	20.38		75	

4. Calculate emission and resource use factors by normalising the data from step 3 to a production of e.g. SEK 1 million for each sector.
5. Identify the final demand of the different product groups (sectors) related to the final demand of the system or product studied.
6. For all product groups included in the final demand: Calculate the required production of input from all other product groups to meet the final demand of this product group.
7. Multiply the calculated production values for each product group by the factors on emissions and energy use from step 4, and aggregate the environmental impacts caused by different parts of the refinement process for each product group.
8. Aggregate the environmental impacts caused by the various sectors resulting in the total environmental impact of the system or product studied.

Step 6 and 7 are best performed using mathematical operations on matrix representations of the data defined in step 1, 2, 3, 4 and 5. An illustration of how this is done is given in the report "Economic Input-Output Models for Environmental Life-Cycle Analysis"[5].

Comparison between IOA and LCA

Input - output analysis (IOA) is a top-down approach in which the statistical data on production and consumption in individual sectors allows a complete allocation of all activities to all products. An LCA-like result can be obtained by linking this with statistical information on environmental exchanges for the same sectors. LCA, on the other hand, is a bottom-up approach in which various unit processes are aggregated into a technical system, describing the manufacture of a product or its entire life cycle, for example. Depending on the scope of the study, an LCA may include all phases from cradle to grave in the assessment of a product or service. In an IOA, the use phase and end-of-life phase are not included in the environmental impact caused by a product. These environmental burdens are instead allocated to sectors providing services needed for the use and disposal of the product. If, for example, the environmental impact of a car is to be assessed, its use and disposal is normally included in an LCA. In an IOA, use and disposal is not included in the environmental impacts from the product category cars. The environmental impacts caused by the fuel needed to run the car, and its disposal are instead included in other product categories[7].

Hence, a fundamental difference between LCA and IOA is the subject of the study. In an LCA, the subject of the study is a product or function. In an IOA, the subject is usually final demand in a country (or a region, an organisation, a company, etc.). The environmental impact in the country can be divided between sectors or product categories. In an LCA, the basis for the assessment is the functional unit, which describes the function provided by the product or service. All downstream and upstream inputs and outputs needed to achieve this function are assessed. In an IOA, the basis for assessment is the final demand in an administratively limited area, typically a country. In IOA, each product in the final demand is followed backwards in the supply chain[8]. There are often geographical boundaries affecting data availability, which makes it impossible to follow a supply chain over a geographical border. This can be resolved using import statistics and IO tables in the national accounts of other countries, to assess what environmental burdens a demand causes in other countries.

Using LCA reveals important aspects of real systems. In LCA it is important that results reflect realities. This requires knowledge of the specific systems, not merely "average data", as in the case of IOA. In addition, LCA provides information on minor details with major impacts. IOA has the advantage of being complete in that it includes all relevant activities relating to a product. However, an IOA is not very detailed, since it relies on a grouping of activities in a limited number of sectors. This makes it difficult to use for detailed LCA purposes, except for very homogenous sectors. Also, the necessary environmental statistics are not always available, which means that adequate information will be missing for some environmental exchanges[9].

Combining process-based LCA and IOA in what has become known as “hybrid analysis" may yield a result possessing the advantages of both methods (i.e. both detail and completeness)[10].

National account statistics can also be combined with design support methods (described in 3.3.1.2), which help the designer to choose between alternative designs.

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[1] Leontief W (1986): Input-Output Economics (second edition), Oxford University Press, Oxford.
[2] Naturvårdsverket (2002), *Kunskap om produkters miljöpåverkan : vad ger dagens statistik?*, Swedish EPA Report 5231, p 28.
[3] Naturvårdsverket (2002), *Kunskap om produkters miljöpåverkan : vad ger dagens statistik?*, Swedish EPA Report 5231, pp 27-28.
[4] www.scb.se.
[5] Hendrickson C, Horvath A, Joshi S and Lave L B (1998), *Economic Input-Output Models for Environmental Life Cycle Analysis*, Environmental Science & Technology.
[6] Nielsen, Weidema (2001), Input/Output analysis - Shortcuts to life cycle data?
[7] Naturvårdsverket (2002), *Kunskap om produkters miljöpåverkan: vad ger dagens statistik?*, Swedish EPA Report 5231, pp 23-24.
[8] Naturvårdsverket (2002), *Kunskap om produkters miljöpåverkan : vad ger dagens statistik?*, Swedish EPA Report 5231, pp 23-24.
[9] Nielsen, Weidema (2001), Input/Output analysis - Shortcuts to life cycle data?, pp 7-8.
[10] Nielsen, Weidema (2001), Input/Output analysis - Shortcuts to life cycle data?, p 8.

Example 5: OMNIITOX

Background

OMNIITOX (Operational Models aNd Information tools for Industrial applications of eco/TOXicological impact assessments) is an EU project under the "Competitive and Sustainable Growth" programme, running from 2001 to 2005[1]. The aim is to facilitate decision making regarding potentially hazardous compounds by developing operational methods and information tools necessary for impact assessment of toxic chemicals within Life Cycle Assessment (LCA) and (Environmental) Risk Assessment (E)RA. The project involves partners from the authorities[2], the academic world[3] and industry[4].

OMNIITOX Information System

One result of the project is the OMNIITOX Information System (IS); see Figure 1 below.[5]

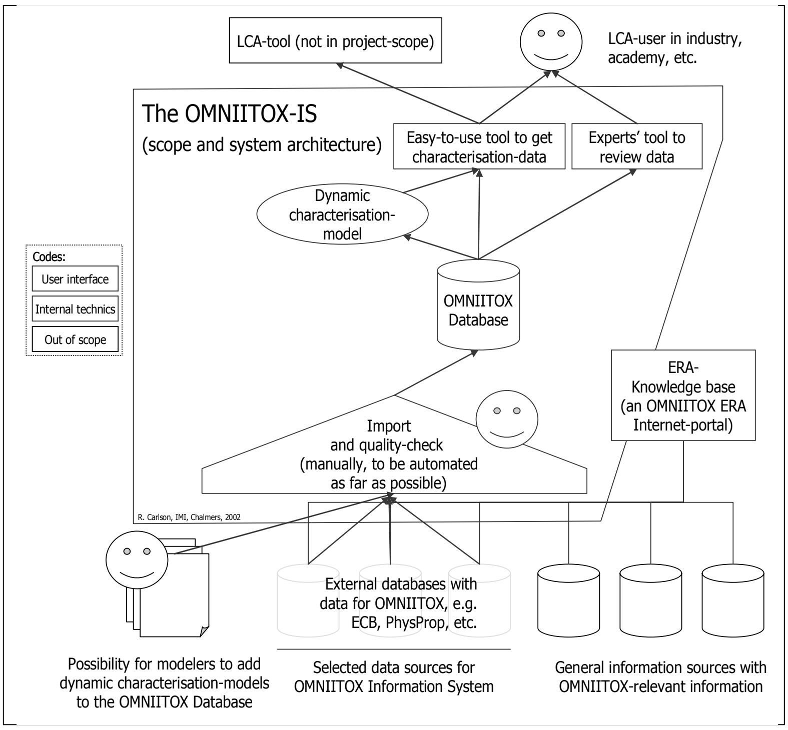

Figure 1 The OMNIITOX information system - scope and architecture[5]

OMNIITOX IS was not publicly available when this report was written, since the developed characterisation models for toxicological impact must be further tested and reviewed before it can be generally recommended for use in LCA and ERA, according to the toxicology and modelling experts involved in the project.

Nevertheless, the IS includes a database with over 100,000 chemicals, 65 substance properties and 144 nature properties. Some of the data have been transferred from IUCLID[6], some have been manually entered by companies and reviewed by the industrial environmental informatics group IMI[473]. There are also two dynamic characterisation models, developed by toxicologists and nature modellers and interpreted and implemented by IMI.

OMNIITOX Concepts and Methodology

One of the advantages of this tool, compared with other impact assessment tools, is that it enables transparent documentation of the characterisation models, so that the indicator, the mechanism and the nature system can be easily identified; see Figures 2 and 3. Thus, it is easier for the LCA practitioner to choose characterisation models based explicitly on the Goal and scope definition[7].

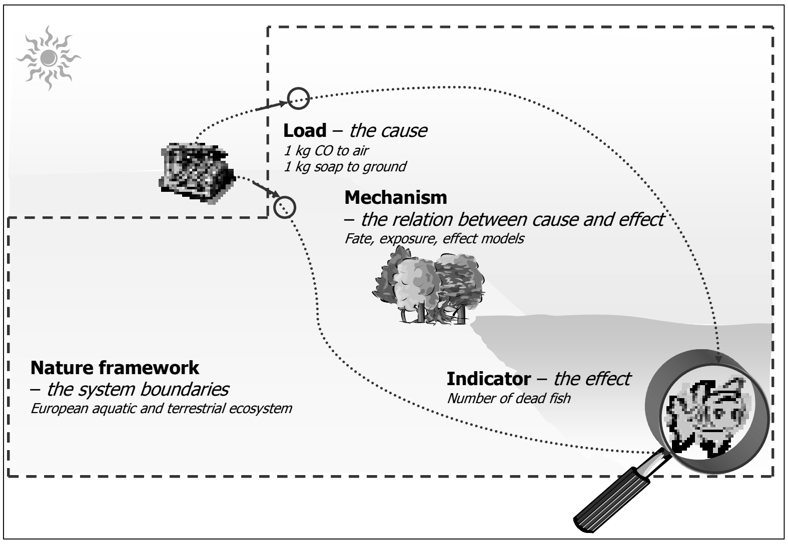

Figure 2 The main concepts in OMNIITOX IS and their relationships; see Figure 3 for a logical representation.

According to ISO 14042, a characterisation model in LCA describes the relationship between a cause and an effect. The load concept refers to the definition of the cause of the environmental impact, and the indicator concept refers to definitions of environmental effects under consideration. The mechanism concept refers to the relationship between load and indicator and determines the magnitude of the impact on an indicator per unit load, expressed as characterisation parameters. A characterisation parameter that makes the characterisation result directly proportional is called a characterisation factor in ISO 14042. The nature framework concept refers to system frame models of the environment. The substance concept is a crucial part of the models and terminology within all disciplines relevant to OMNIITOX. In OMNIITOX IS a substance consists of physical matter, which may be an element, a chemical, a compound, a material, etc.

[473] IMI's homepage: http://www.imi.chalmers.se/.

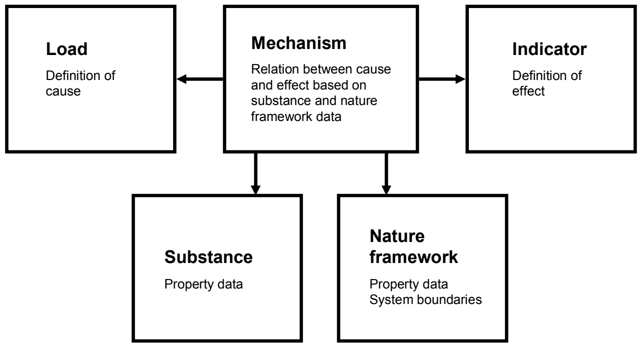

Figure 3. A logical representation of the main concepts in OMNIITOX IS and their relationships.

The interconnection of mechanisms implies a widening of the overall system boundaries (see Figure 4), i.e. the connected sub-mechanisms are all members of a superior mechanism. If the inner structure of the superior mechanism is disregarded, it is itself a "unit" mechanism. The superior mechanism can in turn be incorporated as a sub-mechanism of yet another mechanism. In this way an arbitrary number of sub-levels of mechanisms with differing levels of detail and resolution can be transparently interconnected in the same model using the same core concepts.

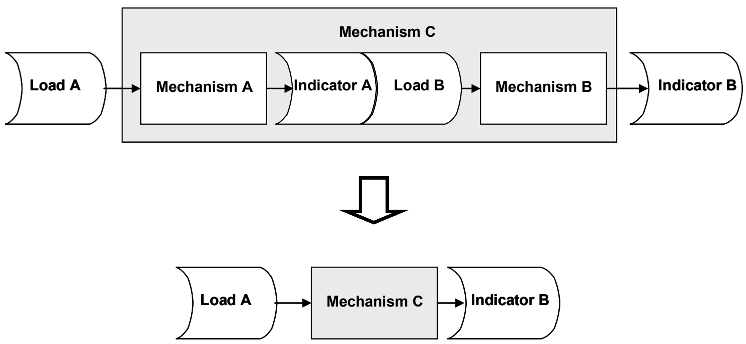

Figure 4. shows that the superior mechanism C containing mechanism A and B can be regarded as a 'unit' mechanism. In this way an arbitrary number of sub-levels of mechanisms may be modelled, documented, and communicated using the OMNIITOX core concepts. Arrows indicate causality.

The OMNIITOX IS User

At present many LCA practitioners exclude the assessment of toxic effects in LCA because the available models produce such different results. Hopefully, LCA practitioners will be able to use the characterisation factors from the human and ecotoxicological characterisation models developed in the OMNIITOX project with ease in the future. If these factors become those recommended by European experts for use by all LCA practitioner when performing impact assessment to indicate toxic effects, the project will have achieved parts of its objectives.

However, the intended user of OMNIITOX IS is an expert in toxicology and modelling, like the experts involved in the OMNIITOX project, or someone needing substance data on various physical and toxicological properties. An additional modelling tool can also be developed, to make the modelling and implementation procedure more efficient and effective.

In the OMNIITOX project, the indicators are chosen to indicate toxic effects. However, the tool, underlying concepts and methodology can also be applied to other impact categories, i.e. global warming, ozone depletion, acidification etc.

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[1] www.omniitox.net, OMNIITOX project reports: *OMNIITOX information system material*, Erixon, M. Flemström, K., et al, 2004 and *Conceptual model report*, Carlson, Tivander, Erixon, et al 2004.
[2] European Chemicals Bureau (ECB), Joint Research Centre, Ispra, Italy.
[3] Technical University of Denmark; Leiden University, The Netherlands; University of Stuttgart, Germany; École Polytechnique Fédérale de Lausanne (EPFL), Switzerland; Chalmers University of Technology, Sweden.
[4] Volvo Technological Development, Sweden; The Procter & Gamble Company, Belgium; Stora Enso Oyi, Sweden; Antonio Puig, S.A. Spain; Randa Group S.A, Spain.
[5] Carlson, Tivander, Erixon et al. (2004), *Conceptual model report,* OMNIITOX project report 2004
[6] IUCLID – International Uniform Chemical Information Database made by ECB – European Chemical Bureau, European Commission, Joint Research Centre, Ispra, Italy, 2001.
[7] ISO 14040 series, see References.

Example 6: ISO/TS 14048 Data documentation format for process data

What is ISO/TS 14048?

The technical specification ISO/TS 14048 Environmental management – Life-Cycle Assessment - Data Documentation Format[1] (ISO/TS 14048) has been established to increase the availability of life-cycle inventory data. It is a set of named fields intended to aid structuring of stored and communicated information on environmental aspects of technical systems, such as individual processes, product systems etc. ISO/TS 14048 is being developed in an ISO standardisation consensus process, which means that it is widely understood by stakeholders in the LCA community.

The value of ISO/TS 14048 is that it provides a neutral specification of a format for process data. The tools using this data currently have application-specific data formats, and mapping between every format is needed in the absence of a common communication format. With a common format it is only necessary to map each format once to the common format. It is intended that ISO/TS 14048 should serve as such a neutral common format.

"Format" here means any structure consistently used for storing information. This may be a document format with fixed headings as well as a relational database format. "Mapping" means the translation of the meaning of information in different fields. Often information is needed from many sources, from hard copy documents to relational databases.

As an example, the SPINE[2] format has been mapped onto ISO/TS 14048[3] and has been implemented in practice in the web-based tools of the IMI Portal[4] at Chalmers university of Technology.

It is also possible to use the 14048 as a template for a database format that renders mapping unnecessary because there will be one-to-one mapping with the communication format.

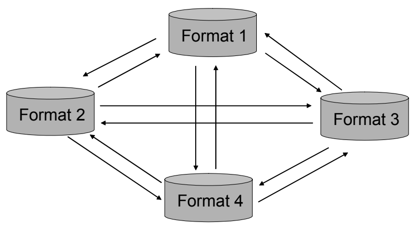

Figure 1. In the absence of a common format, specific mapping must be performed between all formats to exchange information.

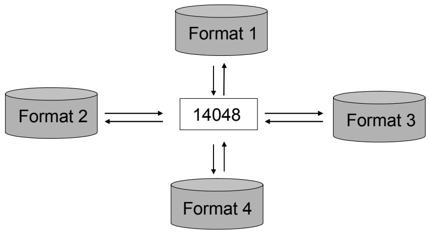

Figure 2. With a common format (14048), each format need only be mapped once.

ISO/TS 14048 as a format for common primary process data

ISO/TS 14048 has been developed for communication of process data in LCA. However, since it is designed to be application neutral, other tools that also use process data can store and communicate process data on the ISO/TS 14048 format. Doing so would make process data entered in one tool available to other tools needing process data.

For example, the European Emissions Trading Scheme (ETS) requires trading organisations to document production facilities (Installations) (e.g. a paper mill) with activities such as fuel combustion emitting carbon dioxide (CO_2). Since estimates of CO_2 output can be based on carbon fuels, these activity data, as referred to in ETS, must also be documented. In the terminology of ISO/TS 14048, an installation is a "process" and an activity is also a "process". In ISO/TS 14048 terminology, the process describing the activity is an "included process". Fuel activity data is an input and CO_2 emissions is an output. By documenting installations and activities using ISO/TS 14048, the data can be reused, e.g. in an LCA study. See Figures 3 and 4.

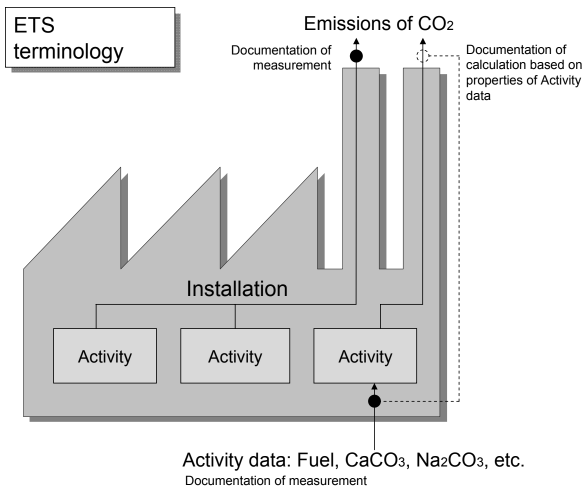

Figure 3 Required documentation in the ETS for CO_2 emissions using ETS terminology.

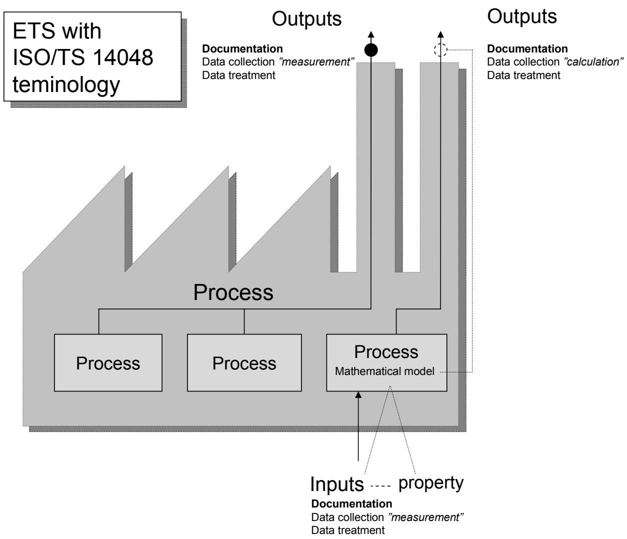

Figure 4 Required documentation in the ETS for CO_2 emissions mapped to ISO/TS 14048 concepts.

The example above highlights similarities between two tools using common primary process data. The ISO technical specification ISO/TS 14048 can serve as a common format suitable for any tool using process data.

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[1] International Organisation for Standardisation (2002), ISO/TS 14048: Environmental management - Life cycle assessment – Data documentation format.
[2] Carlson R., Löfgren G., Steen B.; "SPINE, A Relation Database Structure for Life Cycle Assessment"; Gothenburg; IVL-REPORT; September 1995.
[3] Carlson R, Erlandsson M, Flemström K, Pålsson A-C, Tidstrand U, Tivander J, 2003, Data format mapping between SPINE and ISO/TS 14048, CPM report 2003:8.
[4] The IMI portal - Integrated tools for sustainable development, available through http://www.imi.chalmers.se N.B. The platform supports both the SPINE and ISO/TS 14048 format. IMI recommends using the ISO/TS 14048 for both storing and communicating process data.

Further reading:

Carlson R, Pålsson A-C, 2001, First examples of practical application of ISO/TS 14048 Data Documentation Format, CPM-report 2001:8.
Carlson R, Tivander J, 2001, Data definition and file syntax for ISO/TS 14048 data exchange, CPM Report 2001:9.
Flemström K, Pålsson A-C, 2003, Introduction and guide to LCA data documentation using the CPM documentation criteria and the ISO/TS 14048 data documentation format, CPM report 2003:3.
Flemström K, Pålsson A-C, 2003, An interpretation of the CPM data quality requirements in terms of ISO/TS 14048 data documentation format, CPM report 2003:4.
Flemström K, Pålsson A-C, 2003, Quick guide when switching data documentation format from SPINE to ISO/TS 14048, CPM report 2003:5.
Commission Decision of 29/01/2004, Establishing guidelines for the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council (Text with EEA relevance) Commission Of The European Communities, Brussels, 2004.

Example 7: REACH as a source of common primary data

Aims of REACH

The proposed chemical legislation system under EU – REACH[1] (Registration, Evaluation and Authorisation of CHemicals) - aims to improve the protection of human health and the environment while maintaining the competitiveness and enhancing the innovative capability of the EU chemicals industry. REACH will also impose greater responsibility on industry to manage the risks posed by chemicals and to provide safety information about them. That information is to be passed down the chain of production[2].

REACH is about collecting and disseminating more information about chemicals in our industrial society, since much of this information is currently unknown. Under REACH, enterprises manufacturing or importing more than one tonne of a chemical substance each year will have to register information about the substance in a central database. (Some substances need not be registered, e.g. polymers.) The database will be maintained by the new European Chemicals Agency. Failure to register means that the substance cannot be manufactured or imported.

Primary data collected under REACH

The amount of information to be collected depends on the quantity of the chemical manufactured or imported by the enterprise. A certain set is required for more than one tonne, an additional set for more than 10 tonnes, and further information for the manufacture and import of more than 100 and 1,000 tonnes. More information is also required if a substance is considered to pose a risk.

The data to be acquired by each enterprise for each substance governed by REACH are described below. Unless otherwise stated, this applies to substances produced or imported in quantities of more than one tonne. Enterprises importing or manufacturing the same substance may collect the data and register jointly to reduce costs and the need for testing on animals.

Substance property data

The identity of the substance must be clarified in terms of names from specified nomenclatures or, if the nomenclatures do not include the substance, the molecular formula or unique "fingerprints" of the substance such as chromatograms[3].

Substance property data must be reported for the various manufacturing and import quantities. This covers a range of properties: physical and chemical properties such as melting point and flammability, toxicological properties such as eye irritation and acute toxicity; and ecotoxicological properties such as aquatic toxicity and acute toxicity to fish[4]. The substance property definitions are documented in the proposal[5], which details the methods that can be used to acquire substance property values.

The producer or importer must also provide information on the classification and labelling of the substance[3]. Additionally, for substances manufactured or imported in quantities of more than 10 tonnes it must be stated whether the substance is considered persistent, bioaccumulative and toxic (PBT), or very persistent and very bioaccumulative (vPvB)[6]. However, this information may be derived from other required substance property data.

Product component data
REACH obliges producers and importers to register substances if they are a component of a product, if they meet the criteria for classification as dangerous, are intended to be released during normal and reasonably foreseeable conditions of use, and are present in the product type in quantities of 1 tonne or more per year[1]. Hence, component data on products containing these types of substance must be collected.

Process data
The output flow of the substance from products manufactured or imported must be aggregated for the relevant calendar year. The input quantity of the substance to downstream user(s) is also required. For manufacture, an outline description of the technological process is required[7].

It will also be necessary to acquire outline descriptions of all identified uses of the substance, i.e. process data on how it is used downstream. Outputs from use in terms of waste quantities and composition of waste resulting from manufacture and identified uses will also be required. This includes only waste from the substance in question and not waste from, or emissions of, other substances generated by manufacture and use. The diagram below shows the process data to be collected and registered.

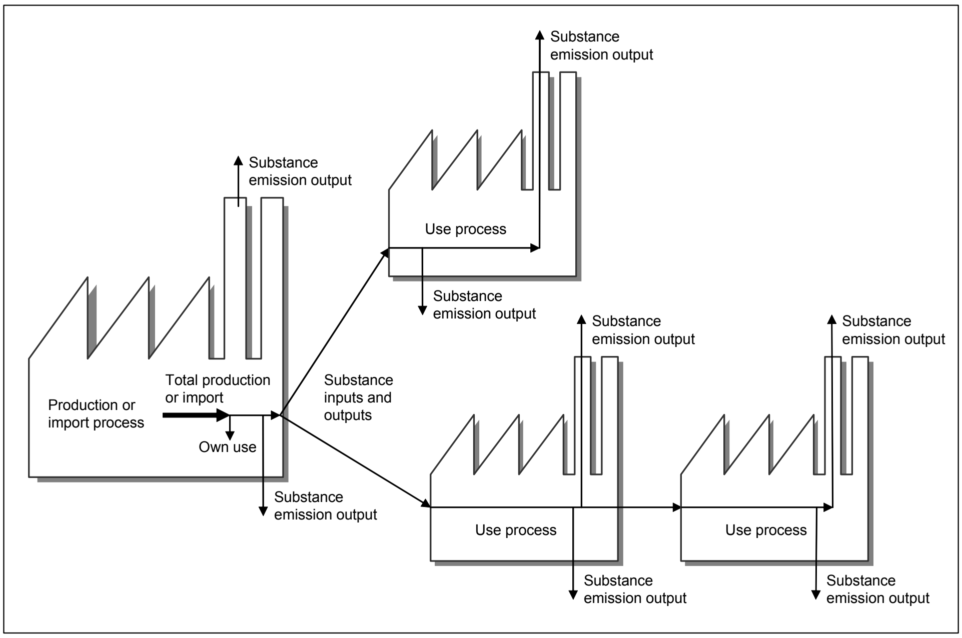

Figure 1: Process data collected and registered under REACH. The downstream data applies to all identified use processes for the substance.

Environmental property and impact data

Specific environmental data must be acquired for substances manufactured or imported in quantities of more than 10 tonnes[8]. In these cases, human health and environmental hazard assessment must be performed to provide estimates of no-effect levels and concentrations, i.e. the threshold levels to which humans and ecosystems can be exposed without any adverse effects. The levels and concentrations are specific to the likely route(s), duration, and frequency of exposure. If the substance is considered hazardous, actual human exposure and concentrations in ecosystems must also be estimated by performing exposure assessment. This yields estimated effect levels and concentrations. The indicator for potential of adverse effects of the substance can then be quantified as the ratio between no-effect level data and effect level data.

Potential use of the primary data in REACH

The data collected will be used in REACH to evaluate substances, and will be a base for the Agency to authorise or place restrictions on their manufacture, import and use.

With other tools, and with LCA in particular, it has been difficult to include impact assessment on toxic effects. This is largely due to the lack of substance property data from toxicity and degradation tests[9, 10, 11]. The substance property data collected under REACH will have the potential to fill many of these gaps.

For REACH data to be useful for other purposes, it is essential that the data be accessible, and that it is possible to assess the relevance and reliability of the data. REACH entails substantial data collection. It is estimated that around 30,000 substances will be registered by 2016[12]. But it is not clear how much of this information will be readily available to the public, since data providers may claim it is confidential for business reasons. Moreover, the numerous requirements governing how to document background data and evaluate their quality may make it difficult to obtain consistent and transparent documentation, leading to difficulties in assessing the quality of the data for various uses.

The technical accessibility of the data will be formatted using software and hard copies in line with formats specified by the Agency. However, it is not known whether other potential uses of the data have been taken into account when developing formats and software.

It is likely that the REACH database will build on the current IUCLID database maintained by the European Chemicals Bureau[13]. IMI has been engaged in interpreting and transferring public data from IUCLID to the OMNIITOX database for use in LCA. IMI found that it was possible to transfer substance property data. However, a specific technical solution was required for each substance property, since the IUCLID data format was highly application-specific and not generically formatted. Since there is neither a documented concept model available for the IUCLID database, nor anyone responsible for knowing how to interpret the entire format, we had to rely on our own judgment and a certain amount of guesswork as to the meaning of data when making the transfer.

REACH aims to improve the protection of human health and the environment while maintaining the competitiveness and enhancing the innovative capability of the EU chemicals industry.

There are many tools apart from those specified in REACH that can use the primary data acquired under REACH and that also are used to this end. Making the data available for these tools might help to achieve the objectives. Data availability for these other tools requires that the information stored in the system can be commonly understood and communicated for different uses. This can be achieved if efforts are made to identify the various uses that share the primary data under REACH and develop a generic data format on the primary level serving as a language between users in different disciplines.

When comparing the requirements under the REACH proposal it may be concluded that it is quite possible to format the required data in line with the generic application neutral data structures in Chapter 4. For example, the substance property data can be formatted according to the data structure described in section 4.3.3.

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[1] Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency and amending Directive 1999/45/EC and Regulation (EC) {on Persistent Organic Pollutants} Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Council Directive 67/548/EEC in order to adapt it to Regulation (EC) of the European Parliament and of the Council concerning the registration, evaluation, authorisation and restriction of chemicals. Available at http://europa.eu.int/eur-lex/en/com/pdf/2003/com2003_0644en.html.
[2] http://europa.eu.int/comm/enterprise/reach/overview.htm.
[3] Annex IV of the REACH proposal.
[4] Annex V-VIII of the REACH proposal.
[5] Annex X of the REACH proposal.
[6] Annex XII of the REACH proposal.
[7] Annex IV of the REACH proposal.
[8] Annex I of the REACH proposal.
[9] Rosenbaum R, Margni M, Charles R, Payet J, Jolliet O, de Koning A, Guinée J, Bachmann T M, Olsen S I, Larsen H F, Birkved M, Hauschild M, Molander S, 2004, Implementation of the OMNIITOX Base Model, OMNIITOX project deliverable 41 Part A.
[10] Olsen S I, Guinée J, Birkved M, Heijungs R, Hauschild M, 2004, Implementation of the OMNIITOX Simplified Base Model, OMNIITOX project deliverable 41 Part B.
[11] Flemström K, Erixon M, Tivander J, Geiron K, 2004, OMNIITOX Information System Material Report, OMNIITOX project deliverable D27.
[12] Kemikalieinspektionen 2004, Faktablad: *REACH en ny kemikalielag för en giftfri framtid*, Fact sheet Alfaprint AB, best nr 510 790.
[13] IUCLID – International Uniform Chemical Information Database made by ECB – European Chemical Bureau, European Commission, Joint Research Centre, Ispra, Italy, 2001.

2 Appendix: Common primary environmental data

2.1.1 Naming, quantification and indicators

2.1.1.1 NAMING AND NOMENCLATURES

The fact that things are named differently depending on context and purpose is of course a problem even in natural language usage, but it becomes a huge problem when information is communicated or used in formal information systems such as computer systems. Thus, the naming of materials, components, etc. must be considered when sharing primary data between different methods and tools.

In spite of standardisation efforts, there often are many parallel naming conventions and nomenclatures for the same thing. For example, a material may have a completely different name when used in different contexts and for different purposes by companies or other organisations. One example is carbon dioxide, which is naturally named CO_2, O=C=O and carbon dioxide[474] in different contexts. To aid understanding of names where standardisation is not feasible, a description of the meaning of a name can be given alongside the name, and the name can be related to the nomenclature or the context in which it is used. Here we mean that a nomenclature is a system of names used in a specific context[475].

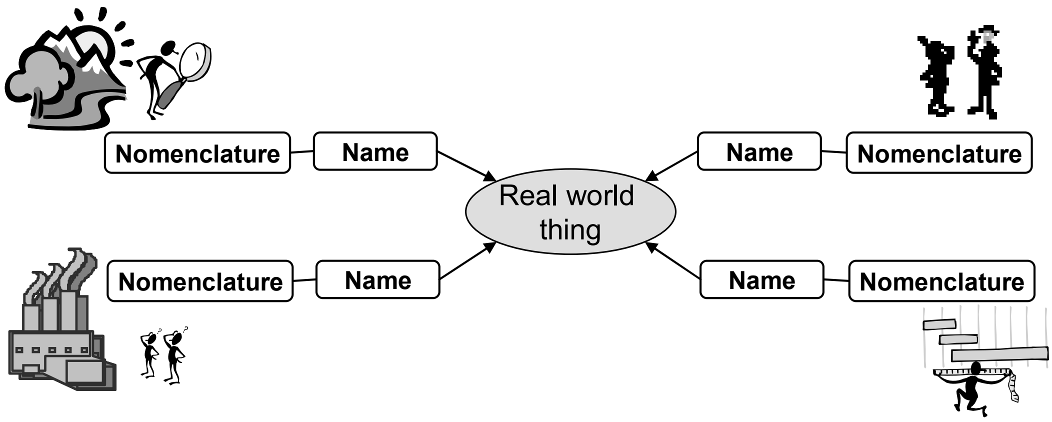

Figure 1. Data structure for names and nomenclatures. A thing may have many different names. Each name belongs to a nomenclature which provides a context for the name.

[474] Flemström K, Geiron K, Erlandsson M (2004), Industrial applications of future information systems for impact assessment - A procedure for data format mapping and nomenclature issues, CPM Report 2004:5, Chalmers University of Technology, Sweden.

[475] www.dictionary.com.

A nomenclature may either be exclusive or non-exclusive. For an exclusive nomenclature, also called an ontology[476], each name has an unambiguous meaning and there is only one name for each concept. In non-exclusive nomenclatures an item may have many names, but each name must have a unique meaning. The choice among different names for the same thing in a non-exclusive nomenclature is based on context. Exclusive nomenclatures are preferable when communicating information between data sources with different nomenclatures, for example.

2.1.1.2 QUANTIFICATION

Most of the methods and tools in chapter 3 need quantitative information input. The quantitative values are based on observations in the world, which involve uncertainties (see section 4.2.2). For some applications it is sufficient to express quantities as single values, but in many cases the uncertainties are also needed for the assessment. The difference lies mainly in data availability and pragmatism; if data is not available, it is pointless requiring it.

However, as described in section 2.2, different users have different needs and requirements as regards statistical data, for example. For the Science and expertise user category it may be important that all detailed quantitative data are supplied with statistical information. The method used to monitor the quantity might call for an uncertainty interval to be specified, with a minimum, a maximum and a typical value for the quantity. If a series of measurements have been performed, all these values could be stored to allow any future statistical treatment within the information system. To generalise this, a quantity could be provided using the name of a distribution function, and names and values for a number of parameters for that distribution function (see Figure 2). In the first-mentioned example above, the name of the distribution function could be Range, with the three parameters Minimum value, Maximum value, and Typical value.

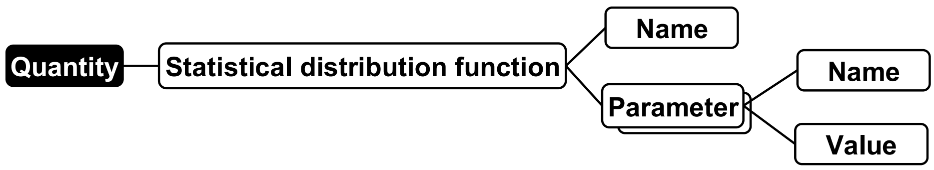

Figure 2. Data structure for quantities

2.1.1.3 INDICATORS

Various environmental indicators are needed to evaluate the environmental performance of activities, processes, hardware, and services, for example[477]. An environmental indicator defines one environmental dimension of a subject of study, e.g. the degree of recyclability of an electric motor, the number of tonnes of carbon

[476] An ontology is a set of concepts - such as things, events, and relations - that are specified in some way (such as specific natural language) to create an agreed vocabulary for exchanging information. - http://whatis.techtarget.com.

[477] Carlson R (2002), *Environmental Performance Indicators*, Published in INSIGHT, Vol 5 Issue 2 July 2002 pp 22-23, The International Council on Systems Engineering (INCOSE).

dioxide emitted by a manufacturing plant, or the increase in the incidence of cancer among a human population due to environmental factors.

The purpose of specifying and using indicators is to have quantifiable representations of things of interest. Indicators may serve as communication keys between stakeholders, since they are definitions of what the quantifiable information actually represents. From the viewpoint of life-cycle environmental impact assessment, the indicators are defined to quantify environmental concerns (ISO 14042[478] terms them "category indicators"). In product specifications, indicators are defined to represent technical performance, etc.

From the viewpoint of structuring information, an indicator consists of a natural name, a formal expression of its unit and an explanatory description. Indicators may be further specified in terms of relevant properties so as to limit misinterpretation. For example, a nomenclature for geographical locations may be used to indicate that environmental impacts have geographical resolution, or it may be of interest to record the valid time span of the indicator. In addition, since an indicator is made from a specific viewpoint, the principle governing its selection should also be included.

Figure 3 shows a data structure for the indicator information, as described above.

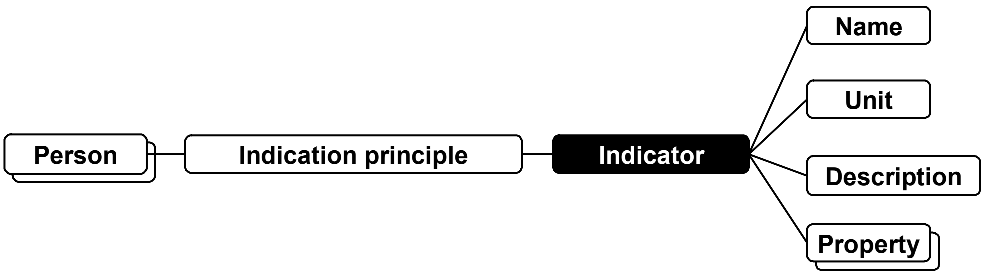

Figure 3. Data structure for indicators

2.1.2 Industrial systems and operations

Common primary environmental data on industrial systems and operations do not address direct environmental changes, but rather effects of human activity that might cause environmental changes. Use of the data on industrial systems and activities for environmental decision making requires explicit environmental data dealing with the effects in nature and subjective environmental data dealing with societal priorities (see also section 4.2.1).

2.1.2.1 SUBSTANCES AND MATERIALS

All of the perspectives from which to environmentally overview product life cycles presented in section 2.3 in some way concern physical matter or substances, such as chemical substances or compounds, or products or materials. All methods and tools described in chapter 3 implicitly also use information and data about physical matter or substances. As described in section A2.1.1.1, the naming of those entities is an important issue. The data structure described here is intended for any physical

[478] ISO 14042 Environmental management – Life cycle assessment – Impact assessment.

matter or substance, be it mineral ore, raw material, energy ware, emissions, waste, products, by-products, waste, recycled material, ashes from incineration, etc.

The data structure in Figure 4 suggests that these data consist of a name and a reference to a nomenclature in which the name is defined. The name and the nomenclature must together unambiguously refer to the intended physical entity. Each material may have many names, each having a meaning in a specific context.

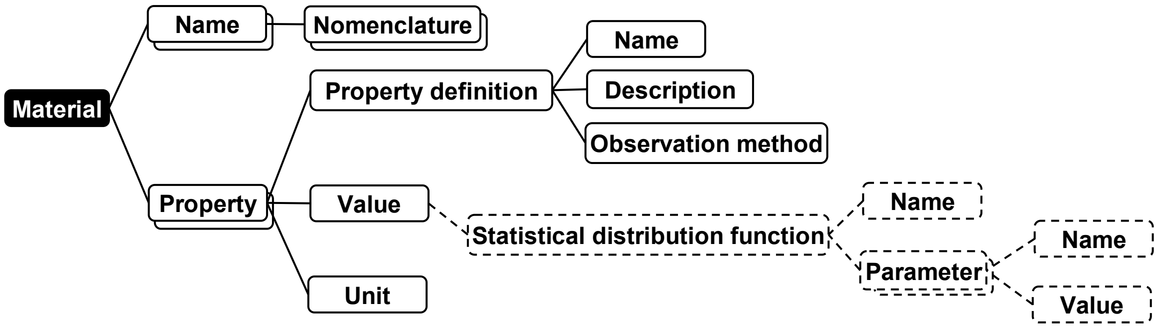

Figure 4. Data structure for material data

Support tools, such as classification lists, restricted and prohibited substance lists, as described in sections 3.4, and analysis tools such as ERA, EIA, and DfE, as described in 3.3, use data on properties of materials. In theory, each material may possess an unlimited number of properties, depending on who is assessing from the applied perspective, e.g. density, toxicity, recyclability, restricted, prohibited, etc. Each property data represents a real world property of the item, and as such it must be clearly defined by a name, a description, and an observation method specifying a procedure to acquire data to quantify the property (see section 4.2.2). Typical property data for physical matter and substances consist of an unambiguous name of the material and a name of the property, a qualitative or quantitative value of the property, and a unit for the property.

Physical matter or substances have different roles in different contexts. For tangible products as described in A2.1.2.2, the materials represent the lowest level for which there is any point in keeping data on products in the information system. For production, transport and services as described in A2.1.2.3, the materials represent inputs that are needed and outputs that are generated in relation to a defined activity. When modelling environmental impacts, these may be caused by extracting or emitting physical matter or a substance. Regardless of context, it is important that the physical matter or substance be properly defined, so that, e.g. two identical materials can be identified in different contexts as the same material in the information system, and vice versa.

2.1.2.2 PRODUCTS

This subsection focuses on the information needed for the tools and methods specified in chapter 3 regarding the material content of the product, how subcomponents in the product are assembled, and some emergent properties, such as noise and energy efficiency. These data are needed by product designers (see, e.g.

sections 2.3.2 and 3.3.1.2), those having reason to assess material content (see, e.g. section 2.3.3), and those assessing the cost of disassembling or scrapping the product (see, e.g. section 3.4.4).

Central data are thus material data, material property data, and information on the way various materials and sub-components are composed in the product. This section provides a general structure for data of this kind.

Material content data
The material inventory methods and tools described in section 3.4.4 and the various decision support tools described in 3.3.1, the variations of LCA methodology described in 3.3.3, and the majority of the methods and tools for technical dialogue described in 3.2 all demand detailed information on the material content of an analysed product. A material inventory consists of a list of material names (see section A2.1.1.1) making up the product. Some applications also need the quantity of each material in the product. For example, the EPD method, as described in section 3.2.3.1, requires the weights of each material. Table 2 below is an example of a material inventory from an EPD. The table summarises the materials used in the TrafoStar 500 MVA power transformer[479] made by ABB Transformers AB, at Ludvika, Sweden.

Summary of materials	**Kg / trafo**	**Kg / MVA**
Transformer oil	63,000	126
Copper	39,960	80
Insulation materials	6,500	13
Wood	15,000	30
Porcelain	2,650	5
Electrical steel	99,640	199
Construction steel	53,618	107
Paint	2,200	4
Other	8,300	17

Table 1. Example of material inventory for the EPD on the TrafoStar 500 MVA power transformer made by ABB. (Trafo is an abbreviation for a transformer and MVA denotes the unit mega volt ampere of electrical power.)

Data on the weight of a material consists of a quantity (see section A2.1.1.2) and a unit, such as 63,000 kg of transformer oil per transformer in the example of material data in an EPD in Table 1 above.

Product and design data
Some methods and tools include product disassembly in the scope of the life cycle, as with the material inventory methods and tools described in 3.4.4 and the DfE tool described in 3.3.1.2. Achieving precision in these methods requires information about the way the components are assembled and where the various materials

[479] EPD for the Power transformer TrafoStar 500 MVA viewed at http://www.environdec.com/reg/e_epd20.pdf.

are located in the product. Data describing these component structures can be produced by relating components to each other. The data structure achieving this is here called a "Composition". Figure 5 shows an example of a component structure. The data example is a product composition in which the component C1344 is made up of the material Fe, and C1344 is therefore given a "parent" role in the structure and Fe that of "child". This data structure is also needed to store environmental data about product components, which is useful when breaking down environmental product requirements into product components or subsystems.

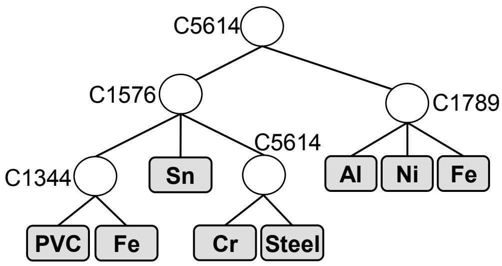

Figure 5. Example of a component structure

The general concept entity

From here we generalise the description of data structures for products, components, material, physical matter and substances concepts and introduce the term *Entity*. An entity is an abstract concept. In one context it may be a product; in another it may be a material or component. The reason for doing this is that the business world, as well as environmental science and management, also regard physical products in this way. A product is made up of components delivered by suppliers. Chemicals may also be products, components, raw materials or emissions. Hence, this generalisation accords with those made in the world of business and environmental management. It also supports an effective and efficient structuring of data for sharing of primary data for different purposes.

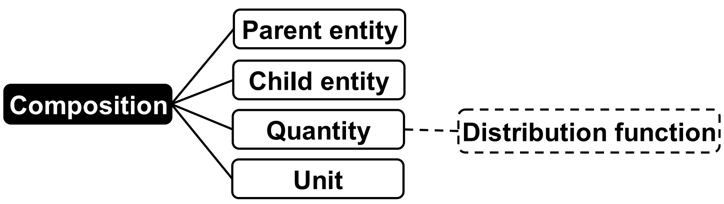

Figure 6. Data structure for composition data. The parent entity is the component such as an engine, composed of one or many child entities, such as engine parts. Each part can be quantified by numbers, weight, thickness etc.

Entity property data

Producing safety data sheets as described in 3.2.3 requires data and information on toxicity, health effects, first aid, reactivity, disposal, protective equipment, and spill/leak procedures. Support tools such as classification lists, restricted and prohibited substance lists as described in 3.3.1, analysis tools such as ERA, EIA, and DfE as described in 3.4.1 and 3.4.2 also use material and component properties to produce results. Using the general Entity concept, we may now call these properties *Entity properties* (see section A2.1.2.1). Entity properties are independent of the place in the product a material or component is being used. They are intended to describe material properties as well as component properties, such as class identifiers etc. Table 2 below shows an example of entity property data for the component structure provided in Figure 7.

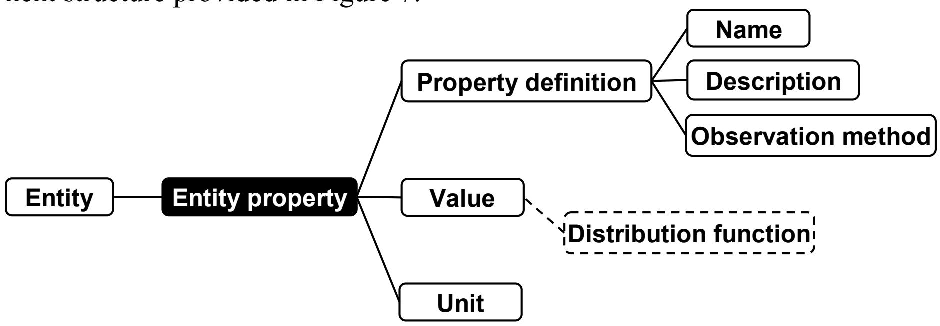

Figure 7. Data structure for entity property data. An entity may be a material or a component.

Entity	Name	Value	Unit
PVC	Density	1.48	tonne/m3
PVC	Potential hazardous waste	Yes	Potential hazardous waste
PVC	Risk of allergy	No	Risk of allergy
PVC	Category	Restricted	Category
C1344	Measured weight	12.3	kg

Table 2. Examples of entity property data for the material and components in Figure 7.

Composition property data

Some methods and tools, such as the DfE method described in 3.3.1.2, must differentiate their results, depending on where a product a material or component is being used in a product. For example, the life span of a property depends on where a component or material is being used. A bolt exposed to dramatic temperature fluctuations may be fatigued more quickly than one in a less extreme environment. For the sake of simplicity, we call these kinds of property *Composition properties.* Unlike entity properties, composition properties may be assigned a value for each occurrence of a material or component in a product. Composition properties are related to the composition of components, materials or a component and a material. Composition property data consists of a *name* of the property, a *value* of the property and a *unit* of the property, if applicable. The property must also be defined in terms of a *description* and an *observation method*.

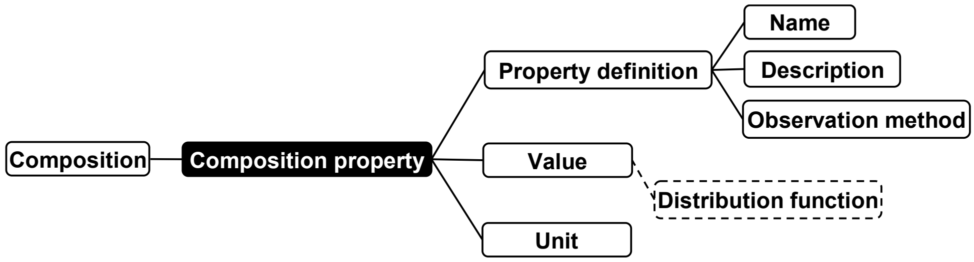

Figure 8. Data structure for composition property data

Child Entity	Parent Entity	Name	Value	Unit
C1344	Fe	Approximated weight	0.356	Kg
C1789	Fe	Approximated weight	21.67	Kg
C1344	C1576	Life span	10	years

Table 3. Examples of composition property data for the material and components in Figure 8.

For all kinds of properties, i.e. both for entity properties and composition properties, it is important to clearly define what the property represents and also how values for the property are obtained. So each property is defined by a description, and an observation method specifying a procedure for acquiring data to quantify the property.

Conjunction data

To correctly assess the environmental aspects of the end-of-life phase of composite products, information about how entities are assembled is needed. These data is managed using material inventory methods and tools as described in 3.3.4, and also DfE tools. Here we call the concept governing this kind of information *Conjunction*. Conjunction information is required for identification of whether two sub-components in a product are glued, welded, snapped or merged together, for example. It is also useful when a material in a component serves as surface treatment of another material. Conjunction data typically consist of a name of the component specifying a conjunction between two of its sub-components or materials, the names of members A and B, which are two sub-components or materials, and finally the roles of the two members in the conjunction (see Figure 9).

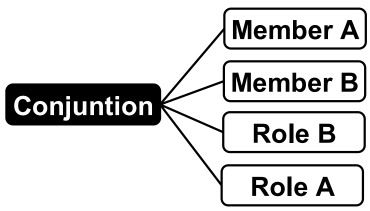

Figure 9. Data structure for conjunction data. A conjunction may be two welded parts, or two parts bolted together with a nut and a screw etc.

Examples of conjunction data for the component structure in Figure 9 are given in Table 4.

Component	Member A	Member B	Role A	Role B
C5614	Steel	Cr	Base material	Surface treatment
C1576	C1344	Sn	Base material	Welding
C1576	C5614	Sn	Base material	Welding

Table 4. Examples of conjunction data for the material and components in Figure 9.

2.1.2.3 PRODUCTION, TRANSPORT AND SERVICES

Analysis methods and tools such as LCA, LCC, EIA, and ERA, as described in 3.3.2 and 3.4.3, and decision support tools such as EMS, as described in 3.3.1.3 require information on resource use, waste generation and emissions relating to the production of a service or product.

Process models and descriptions

As described in section 3.4.1.7 about databases holding data describing technical systems from environmental viewpoints, and in 3.3.3 about LCA, the operations performed when producing a product or service can be modelled and documented using various process models. Here, processes may be well-scoped descriptions of the systems used for manufacture, incineration, transport, raw material abstraction, fuel combustion, or even for use of a product, as well as landfill. A process has inputs and outputs of raw materials, it produces a product, service or other function, it consumes resources and energy, and it produces waste and emissions. 2001 saw the introduction of an international standard for methods of documenting these processes and structuring data and documentation: the ISO ISO/TS 14048 technical specification Environmental management – Life-cycle assessment – Data documentation format[480].

In the terminology of ISO/TS 14048, a *Process* is a model representation of a well-defined part of a technical system with a definite system scope and boundary. The inputs and outputs flowing over the system process boundaries are referred to as *Inputs and outputs* (see Figure 10). A process has as many inputs and outputs as have been identified for the technical system and are relevant for the use of the information. Each input and output represents a substance or energy flow entering or leaving the boundary of the system. Some inputs and outputs may seem more abstract, such as the use of land as a resource in forestry. This presents no problem as long as the input and output are quantifiable in some defined unit. When creating a model of the technical system, i.e. the process, some modelling principles are applied. After the process has been documented, the quality of the modelling and the documentation are validated in various ways.

[480] International Organisation for Standardisation (2002), ISO/TS 14048: Environmental management - Life cycle assessment – Data documentation format.

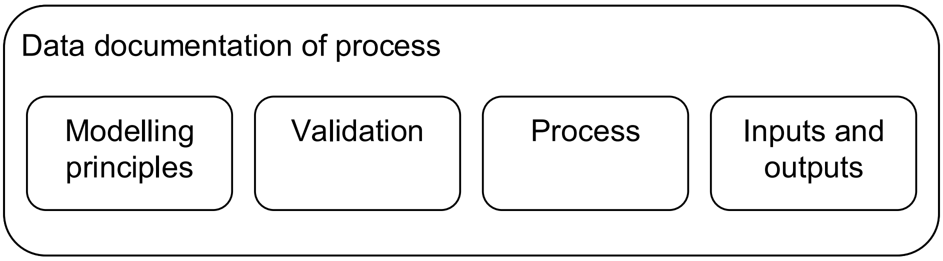

Figure 10. Fundamental concepts of ISO/TS 14048

This conceptual model for LCI data described above and in 3.4.1.7 is used in this report to describe, exemplify and structure data on production and transport. A full description of a documentation format for LCI data is given in the ISO/TS 14048 technical specification.

The actual documentation needed to fully describe a process depends on user categories as described in section 2.2 and on their data quality requirements and criteria. One explicit data quality criterion used is the CPM data documentation criteria[481]. According to those criteria, the model of the process is described by a Name, a Quantitative reference, a brief specification of the Technical scope, together with a detailed description of the Technology, the Valid time span, and the Valid geography.

Inputs and outputs

Data on input and outputs must comprise at least a name, a direction showing whether it is an input or an output, a quantity and a unit. They must be normalised to some quantitative reference, e.g. the production of 1 tonne of steel, or total production in 2004. An example of data on inputs and outputs documented using these data fields is given in Table 5.

Inputs and outputs	Direction	Quantity	Unit
Al	Input	2.36	kg/MVA
Coal	Input	834.35	kg/MVA
Cu	Input	271.26	kg/MVA
Fe	Input	442.98	kg/MVA

Table 5: Example of inputs and outputs from the manufacture of the TrafoStar 500 MVA[482] power transformer by ABB.

Information clearly defining each input and output is also needed to allow a match with relevant data describing what impact the input or output has on the environment. Information is thus needed on the *receiving environment* (for example air, water, ground, technosphere) and the *geographical location* specifying where the process and the inputs and outputs occur. To make the information transparent and

[481] Arvidsson P et al (1997), *Krav på datakvalitet CPM:s database 1997*, CPM Report 1997:1, Chalmers University of Technology, Sweden.

[482] EPD for the Power transformer TrafoStar 500 MVA viewed at http://www.environdec.com/reg/e_epd20.pdf.

reliable, *documentation* describing how the value for the input or output has been acquired should also be provided. The description follows ISO/TS 14048 in terms of the type of *data collection* that has been performed, the *collection date*, a detailed description of the *data treatment* that has been performed, together with a *reference to data sources* that were used. An example of data on inputs and outputs documented using these data fields is given in Table 6.

Identification number	1	2	3
Direction	Input	Input	Input
Group	Ancillary	Raw material	Ancillary
Receiving environment	Technosphere	Technosphere	Technosphere
Receiving environment specification	Technosphere	Technosphere	Technosphere
Geographical location	Sweden	Sweden	Sweden
Related external system	**Origin or destination** Solvent producer **Transport type** Truck	**Origin or destination** Surface coating producer **Transport type** Truck	**Origin or destination** Surface coating producer **Transport type** Truck
Internal location			
Name	**Name text** Solvent **Reference to nomenclature** Company-specific	**Name text** Filler coating **Reference to nomenclature** Company-specific	**Name text** Base coating **Reference to nomenclature** Company-specific
Amount	**Name** Average **Unit** *Symbol or name:* kg **Parameter** *Name:* Average *Value:* x	**Name** Average **Unit** *Symbol or name:* kg **Parameter** *Name:* Average *Value:* x	**Name** Average **Unit** *Symbol or name:* kg **Parameter** *Name:* Average *Value:* x
Documentation	**Data collection** Economic information **Collection date** 1994 **Data treatment** Total quantity of solvent bought in 1994. Adjusted per functional unit. (Total quantity of solvent/ Total quantity painted product units at the production plant) **Data collection** Economic information	**Data collection** Economic information **Collection date** 1994 **Data treatment** Total quantity of filler coating bought in 1994. Adjusted per functional unit. (Total quantity of filler coating/Total quantity painted product units at the production plant) **Data collection** Economic information	**Data collection** Economic information **Collection date** 1994 **Data treatment** Total quantity of base coating bought in 1994. Adjusted per functional unit. (Total quantity of base coating/Total quantity painted product units at the production plant) **Data collection** Economic information

Table 6. Example of inputs and outputs of the process "Painting process at the company's production plant", available in report "First examples of practical application of ISO/TS 14048 Data Documentation Format"[483].

[483] Carlson R, Pålsson A-C (2001), *First examples of practical application of ISO/TS 14048 Data Documentation Format*, CPM Report 2001:8, Chalmers University of Technology, Sweden.

An environmental impact assessment (EIA, see section 3.3.2.2) requires essentially the same kind of data as for an LCA described above, which means that descriptions of processes, and inputs and outputs from those processes are needed. However, generally more precise data with greater local specificity is need for an EIA than for LCA. An ERA also requires data on the risks associated with the manufacture of a product. Information is required on the quantity of hazardous substances emitted from the technical system to the nature system. Risks may be modelled by probabilities that accidental processes will occur; the accidental process is then itself modelled as an ordinary process with inputs and outputs and system boundaries etc, and it may represent a fire in a chemical factory, an exploding tanker or leaking pipeline.

However, the LCA method based on national statistics, as described in section 3.3.3, differs from the other methods since, the material or energy chain, for example, is cut at the national border. National statistical data consist of a summary of all necessary inputs and all resulting outputs in the manufacture of a given product. An example of these data is given in "Example: Input/Output analysis" in Appendix 1.

As described in section 3.3.3.6, life-cycle cost (LCC) includes the cost and time associated with each alternative over a selected analysis period, and conversion of those costs to economically comparable values. Costs may be modelled in various ways using, e.g. the ISO/TS 14048 data documentation format, such as a financial input to a process, as a monetary leakage from a process or as a negative product. Many other options are also available.

2.1.2.4 SCENARIOS, MARKET, USE AND EOL

Methods and tools assessing the environmental burden caused by a product or service from a life-cycle perspective require upstream information about all environmental burdens caused by components and materials making up the product, as well as downstream information about what will happen to it once it has left the production facility. For example, downstream information is needed for DfE tools to optimise design for the use and disposal phase described in 3.3.1.2, for ERA to help identify hazardous situations as described in 3.3.2.2, for LCC to calculate costs during use and disposal as described in 3.3.2.5, and for LCA to calculate the gate-to-grave environmental impact as described in 3.4.3. Upstream information is particularly needed to assess the long-term economy viability of choice of materials and suppliers, for example. The wrong material choice may raise raw material costs, and choosing the wrong supplier may reduce goodwill or cause legal liability.

Data on use

As may be expected, whatever the importance of a life-cycle perspective, the use phase is the most important part of the life cycle of many products from an environmental point of view. This applies to products or services for which energy use or emissions during use are central aspects, as well as products where waste treatment and material-efficient use of goods are important. Generally speaking, a careless or uninformed user can waste any good DfE effort, and a careful and environmentally conscious user can make the best of even environmentally disastrous products. The use phase must therefore be included in any assessment of the environmental life-cycle performance of a product.

An example of data from the use phase is use patterns, which can be used to generate information on energy use, emissions and service intervals for various use scenarios, ranging from normal to extreme in various respects.

Various models and data structures may be envisaged for sharing data of this kind, but it is easy to see how different use scenarios may be modelled as different use processes for the same product, using the ISO/TS 14048 data documentation format.

Data on end of life (EOL)

The end of life (EOL) of products is important since it has implications for recyclability, energy recovery, landfill, abstraction of virgin natural resources, etc. Improved EOL can be achieved if the scrapping process is determined during product design, if preferred waste management is known by the user, or if the waste manager has detailed knowledge of disassembly procedures and the material contents of the product, for example.

One example of this is the Swedish Producer Responsibility for Motor Vehicles Ordinance[484], which obliges vehicle manufacturers to supply information about materials, components and chemicals to the waste manager (see section 2.3.3).

EOL data include the recycling rate of the materials used in the product, reuse of components in the product, quantity of hazardous waste, and energy recovery when incinerating the product. This information is obviously related to decisions in the design phase on material choices and how parts are assembled. End-of-life data resemble data from the use phase.

2.1.3 Environmental change and impact

Information about the nature system, as defined in 4.2.1, is needed to be able to quantify environmental impacts. Hence, the methods and tools described in chapter 3 covering models to quantify environmental impact require specific environmental information, e.g. LCA, ERA, EIA, design for environment and green procurement. The complexity and level of detail of these impact assessment methods vary greatly from one tool to another. However, all impact assessment methods share a common structure comprising information on the part of the nature system considered, one or several quantifiable indicators representing environmental concerns, one or several quantifiable environmental aspects of human activities, and information on how the environmental aspects relate to the indicators, i.e. the extent to which the changes in the indicators are due to changes in the environmental aspects.

[484] Sveriges riksdag (1997), *The Producer Responsibility for Motor Vehicles Ordinance*, Svensk författningssamling (SFS) 1997:788.

2.1.3.1 SUBSTANCES AND MATERIALS

Information about substances and materials is described as information on industrial systems and operational information in section A2.1.2.1. However, information about substances and materials is also information about the nature system. The same chemical and physical properties of a substance or material that give the desired technical qualities are also relevant when determining the potential environmental impact (antifouling agents in marine hull paint being a good example).

Using *exactly* the same data structure for substance and material properties regardless of whether the context is the technical system or the nature system is not only practical and a means of ensuring efficient management and compatibility of the information. The substance and material properties are *exactly* the same information. Thus, the data structure in Figure 4 and the information are used in the same applications: classification lists, restricted and prohibited substance lists, impact assessment tools such as ERA, EIA, and DfE.

2.1.3.2 INDICATION OF ENVIRONMENTAL CHANGE AND IMPACT

All tools described in chapter 3 that include environmental impact assessment methods require information on the environmental change or impact that is being quantified. The definitions of what is quantified are essential to allow communication and understanding between information suppliers and users. For the sake of simplicity, these definitions of effects quantified in environmental assessment tools are all referred to in the following as indicators. The general information structure of indicators described in A2.1.1.3 also applies to these indicators. This chapter focuses solely on the physical representations of indicators in nature. Information on subjective reasons for choosing and assigning values to indicators is described in chapter 2.1.4.

As explained in chapter 3.3.1.1, information about the supplier's environmental performance is required for procurement purposes. One of the most common examples of environmental information communicated in industry is whether the supplier has implemented an environmental management system or not. This is a highly condensed indication that the supplier is aware of and takes measures to reduce its environmental impact without specifying what impact is reduced. Further information requirements may concern the environmental performance of the suppliers' products and processes in terms of specific indicators such as recyclability, energy efficiency, quantity of hazardous materials There must be an understanding between the purchaser and the supplier about what the indicator represents and how to quantify it.

Indicators in the form of environmental performance indicators and environmental aspects are key information in DfE to quantify the environmental performance of a product, as described in chapter 3.3.1.2. They specify the environmental impacts being evaluated amongst the aspects of the product that the designer can control. Typical examples of indicators used in DfE are recyclability, number of materials, number of restricted materials, ratio between weight of known materials and total weight of the product, greenhouse gas emissions generated to produce the materials, and components and assembly of the product. The indicator is only the specification of what is actually quantified; some indicators do not always obviously indicate environmental change. Yet they still represent environmental concerns such as scarcity of resources, toxic effects, climate change, etc. The full environmental mechanism leading to the environmental effects of concern is only implied. For example, high recyclability is an indication of avoidance of scarce resources and increased concentrations of artificial materials in nature. As with green procurement, there must be an agreement between suppliers of material and components and designers about which indicators to quantify and communicate.

LCA methods term indicators "category indicators" (see chapter 3.3.3). The desire in LCA practice for a total overview of the environmental impact of a life cycle system has led to the inclusion of quantifications of several indicators for a wide variety of concerns. Examples of indicators used in LCA are years of lost life, release of H^+ ions, normalised extinction of species, stratospheric ozone depletion potential, number of persons with cancer, etc. Depending on the goal and scope of a study and the type of environmental impact, indicators may be specified in terms of geographical location, environmental compartment, time horizon, etc. For example, acidification indicated by release of H^+ ions may vary greatly with geological conditions and it may be of interest to have a geographical differentiation of these indicators, whereas ozone depletion indicated by the ozone depletion potential of emissions is regarded as a global effect, regardless of the geographical location of the emissions, and this indicator therefore requires no geographical resolution. To indicate toxicity, a time horizon of 50 years may be specified, so as not to overestimate the impact of substances that degrade very slowly in nature when using toxicity impact quantification models not considered to apply over infinite time.

In ERA methodology as described in chapter 3.3.2.2, the result of the risk characterisation is a quantification of the indication of risk. Hence, the ERA indicator is the estimated ratio between the environmental concentration of a substance, called PEC (predicted environmental concentration), and the maximum environmental concentration of the substance before it results in toxic effects on organisms, called PNEC (predicted no effect concentration).

Indicators to quantify environmental impact are used indirectly to assess external environmental costs within the Life Cycle Cost (LCC). Environmental impact is assigned a monetary value. Depending on the type of impact, there may be business models implemented that internalise environmental impact so that it represents a cost to the organisation causing it, such as in the European Emissions trading Scheme (ETS)[485] for greenhouse gases, or as taxes or fees for the right to emit substances in nature. For environmental impacts for which business models of this kind have not been implemented, further external costs may be assessed by the supportive use of LCA or other tools by using a cost-based weighting of the indicators. Indicator values are further described in chapter 2.1.4.1.

[485] Commission Decision of 29/01/2004, Establishing guidelines for the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council (Text with EEA relevance) Commission Of The European Communities, Brussels, 2004.

Assessment of the overall environmental performance of a company can be made under an environmental management system (EMS); see chapter 3.3.1.3. The indicators quantified may be identical to indicators used with other tools such as DfE or LCA, e.g. recyclability, emissions of greenhouse gases, aquatic ecotoxicity, years of lost life. The differences may concern aggregation in time or geography if these dimensions are considered. For example, the geographical distribution of aquatic ecotoxicity may be assessed for a specific production plant. At corporate level, it may be appropriate to define an indicator at global level.

To sum up: an environmental impact indicator is a quantifiable entity in nature. The purpose of defining an indicator is to have a quantifiable entity representing real or potential environmental change of concern. The use of indicators is inherent in any tool that includes assessment of environmental effects.

Following the indicator data structure described in chapter 2.1.1.3, some examples of indicator information are exemplified in Table 7.

Indicator name	**Unit**	**Geographical location**	**Valid time span**	**Description**	**Environmental concern**
Years of lost life	year	World	1 Jan 2005 - 31 Dec 2054	The total number of human life years lost in a defined population	Human life span decrease
Greenhouse gas emissions	t	World	1 Jan 2005 - 31 Dec 2005	Metric tonnes of CO2 equivalents emitted to air from the technosphere	Climate change
Aquatic ecotoxicity in Sweden 2004	m^3	Sweden	1 Jan 2004 - 31 Dec 2004	The quantity of unpolluted water needed to dilute a toxic substance to maintain a non-toxic effect concentration.	Degradation (loss) of resources and increased concentrations of toxic substances in nature
Aquatic ecotoxicity in Denmark 2003	m^3	Denmark	1 Jan 2003 – 31 Dec 2003	The quantity of unpolluted water needed to dilute a substance to maintain a non-toxic effect concentration.	Degradation (loss) of resources and increased concentrations of toxic substances in nature.

Table 7. Examples of indicator information

2.1.3.3 MODELS TO QUANTIFY ENVIRONMENTAL CHANGE

The tools for environmental assessment that use environmental condition indicators[486] also require information on how to quantify the environmental impact on the indicator. Environmental impacts cannot usually be directly measured. One exception is in EIA, where the focus is on site-specific local impact. Here, direct measurements may be used to describe the surrounding environment. Environmental management systems may also include direct measurement of the environmental

[486] As specified in ISO 14031, International Organisation for Standardisation (1999), *ISO 14031: Environmental management - Environmental performance evaluation – Guidelines.*

effects of local environmental aspects[487]. In general however, information on environmental impact is quantified using models.

Environmental impact models are based on information about environmental mechanisms. The mechanisms are described as quantifiable relationships between specified loads representing causes and specified indicators representing effects.

If the load refers to environmental aspects in the technosphere such as emissions or material properties in a product, the environmental impact model can be used to assess the environmental performance of the products and processes. This serves as an interface to implicit environmental information and allows assessment of the environmental performance of products and processes. See the description of technical process information in chapter A2.1.2.3.

The models are representations of different parts of nature in terms of geographical coverage, time coverage, geophysical media distribution, etc. For instance, a model may cover a specific geographical location, e.g. Sweden or Europe, or a specific type of ecosystem, e.g. freshwater bodies or the tropical climate zone. This information constitutes the system boundaries of the model.

Since it is not possible to have continuous access to every unique piece of information in the system, simplifications are needed. Environmental systems analysis is used to find a set of properties within the nature framework that significantly influence the cause - effect mechanism. These analytical points can be classified as substance properties and nature properties (or substance-independent properties). These are further described in chapters A2.1.3.3.

An impact model contains both quantitative and qualitative information. Quantitative information defines the mathematical algorithm describing how to calculate the change in the indicator due to a change in the load. In particular, the algorithm prescribes the analytical data points in terms of substance and nature properties that are required as input parameters. The qualitative model information describes the physical representation of the quantitative model, i.e. what environmental mechanisms are modelled, reasons for inclusion or exclusion of mechanisms, etc.

Figure 11 shows the structure of information on environmental impact models.

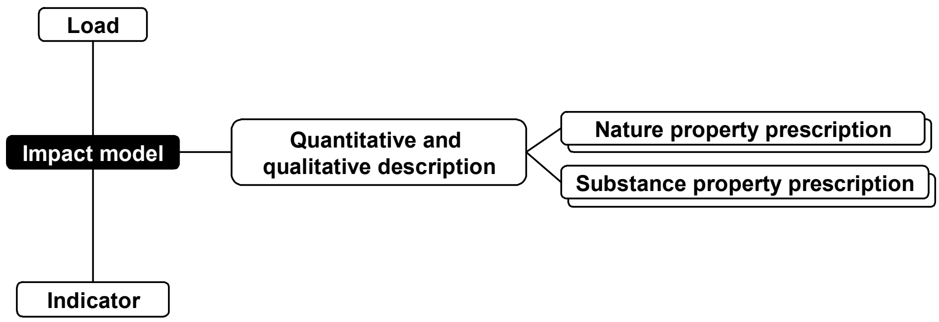

Figure 11. Data structure for information on environmental impact models. The mechanism impact model describes the relationship between a load and an indicator and requires substance and nature property data to quantify the impact on the indicator.

[487] Pålsson A-C (2003), *Rapport från förstudie i CPM projekt A20*, CPM Report 2003:2, Chalmers University of Technology, Sweden.

The environmental impact assessment models in LCA are called characterisation models. Most characterisation models use "characterisation factors", which describe a linear relationship between load and indicator. When performing an LCA study it is often considered sufficient to have access to the aggregated characterisation factors, since the underlying model defining these factors is too detailed. However, this is also a result of insufficient documentation of the available models to date, to the point where it is not possible for anyone other than possibly the model creators to reproduce or to create new characterisation factors. The OMNIITOX information system (see Appendix 1), developed under the OMNIITOX project, addresses the needs of scientists and experts for transparent information on the characterisation model algorithm, and also provides tools for the LCA practitioner to use the characterisation models. This has been achieved by ensuring that the modelling experts can provide model data including prescriptions of the required property data, and an LCA practitioner can provide the necessary substance property data to calculate the characterisation factors applicable to their study.

The information in an ERA impact model consists of the mechanism describing the predicted environmental concentration (PEC) due to the production and use of a chemical product. This is normalised with a predicted no-effect concentration (PNEC). This requires toxicity test data together with an algorithm that extrapolates from no-effect in controlled laboratory conditions to a no-effect level in an ecosystem. The algorithm in ERA may require data only available in a form with little precision or low credibility. To avoid underestimating the risk of low quality data, assessment factors are used in the algorithm. These increase the estimated impact on the indicator.

Substance properties

Information on substances and substance properties is described as information for both industrial systems and operational information in section A2.1.2.1, and as environmental change and impact information in section A2.1.3.1. As with implicit

environmental information, substance nomenclatures are used to identify the substance being considered. For effective substance data management, the information is broken down into the name of the substance with a reference to the nomenclature used, the name and specification of the substance property and the value of the property, together with qualitative information on the method used to acquire the value. A substance property specification includes information on applicable observation methods to acquire a value. Many substance properties are also dependent on environmental conditions such as pH and temperature. Depending on the level of detail of the environmental impact model used, details of conditions may be required. Examples of substance properties are mass, colour, dissociation constant, degradability, acute toxicity to fish, etc. Figure 12 illustrates the structure of substance property data.

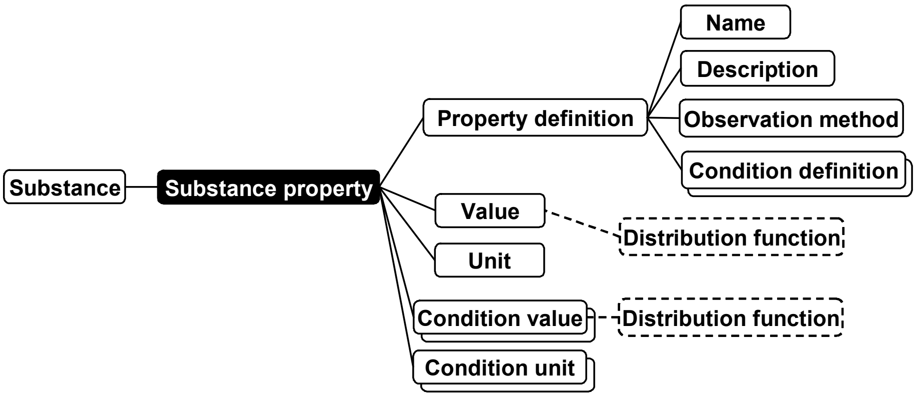

Figure 12. Data structure for information on substance properties

Nature properties
Examples of nature properties are geographical location, wind speed, time span of rain period, etc. The structure of nature property data is similar to substance property data. A specification of a nature property tells how to acquire a nature property. The system boundaries in impact assessment models set the limits for which the value applies. The property can be acquired and recorded for defined nature system boundaries of an impact assessment model; see Figure 13.

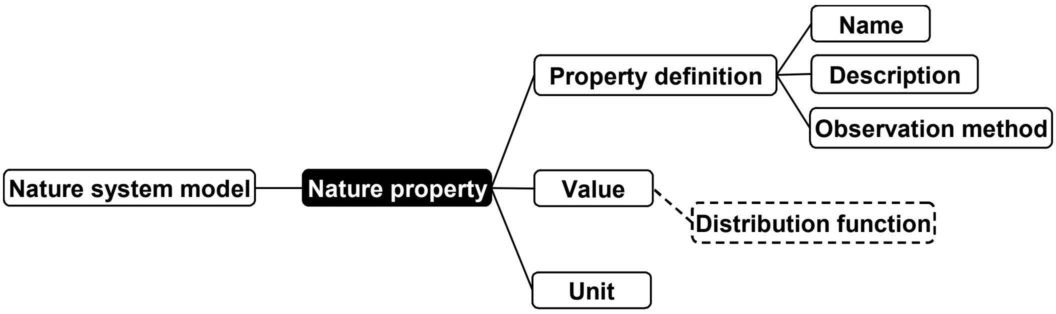

Figure 13. Data structure for information on nature properties. A nature property value is defined by referring to a nature framework and a nature property specification.

2.1.4 Priorities, Policy and valuation

2.1.4.1 CHOICE AND VALUE OF INDICATORS

As described in chapter 2.1.1.3, environmental indicators are defined as quantifiable representations of environmental concerns.

The impact indication principle, i.e. the policy and principles governing definition of the indicator, may be based on corporate environmental policy, references to legislation, etc. For example, the legislative framework under the EU Emissions

Trading Scheme[488] may be cited as the reason for quantifying greenhouse gas emissions for organisations in the trading sector.

The information on those choosing and assigning values to indicators may be references to a single individual, the population of Europe between the ages of 18 and 65 years, a company policy team, etc.

Many indicators used in tools require the user to have expert knowledge of environmental mechanisms to understand what they represent and how they can be compared and given priority in relation to other indicators. To assess the impact on more than one indicator, each indicator can be assigned a subjective value or significance. This will allow comparison between indicators and priorities as to which impact has the highest priority for reduction. These priorities and values may be based on corporate policy, estimates of the external cost of the environmental impact, legal boundaries imposing a cap on an impact, etc.

Information on the value of an indicator can be documented as a weighting factor or in relation to a target value. A weighting factor is information on the value per unit change in the indicator. When multiplying a quantified impact on an indicator by a weighting factor, environmental impact is translated into a value-based unit such as cost. Priorities set in this way are always subjective. Table 8 shows examples of weighting factors allowing comparison of a set of three indicators.

Indicator name	Indicator unit	Weighting factor	Weighting factor unit
Greenhouse gas emissions	t	40	€/ t
Aquatic ecotoxicity	m^3	0.05	€/m^3
Years of lost life	year	75,000	€/year

Table 8. Example of weighting and factors allowing comparison of three indicators

ISO standard 14042 for LCIA states: "The selection of impact categories must reflect a comprehensive set of environmental issues related to the product system being studied, taking the goal and scope into consideration" [489]. Thus, there is no requirement that any specific environmental concerns be considered in LCA other than that they should be appropriate for the purpose of the study. A common practice in LCA is to quantify effects on indicators based on the characterisation models available in the specific software used by the LCA practitioner. It is also possible to add characterisation factors found more appropriate for the study. The LCA impact assessment method includes an optional weighting step. This requires information on the values of indicators in the form of weighting factors, which are included in many impact assessment methods.

[488] European Commission (2003), Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC.

[489] International Organisation for Standardisation (2000), ISO 14042: Environmental management - Life cycle assessment – Life cycle impact assessment.

2.1.4.2 GOALS AND REFERENCE VALUES

In ERA methodology a risk characterisation value higher than 1 is considered a risk and therefore requires further assessment and risk management measures. Here, a value above 1 is an agreed and chosen reference value representing the human notion of risk or no risk.

Target values for environmental performance indicators in DfE and green procurement can be set by the design customer or the purchaser. If the designer cannot find designs meeting all targets, further priorities as to which goals are most important may be specified to aid the designer's decision. An example is given in Table 9.

Indicator name	Unit	Target	Priority
Recyclability	Percentage of total weight	>80%	1
Emission of green-house gases	t (CO_2 eq)	<50 t	2
Known material ratio	Percentage of total weight	>90%	3
Number of materials	-	<10	4

Table 9. Examples of typical environmental performance indicators applicable in DfE, with target values and priorities

These are examples of reference values that can be compared with the quantified values of indicators. Any decision support tool requires reference values of this kind. The reference may not always be explicitly documented, since it is often referred to as "common sense". A descriptive study may not need clarifying documentation on the value of the indicator when it is represented by an obvious desired environmental change, e.g. increased eutrophication is considered to be a bad thing and vice versa.

3 Appendix: Availability of various types of data

3.1 Examples of nomenclatures for materials

3.1.1 Material nomenclatures:

- **CAS number**[490]
  Publicly available and maintained data resource containing CAS (Chemical Abstracts Service) Registry Number, unique identification numbers of more than 100,000 chemicals. CAS numbers are made up of numbers separated by hyphens. They may contain nine digits. This nomenclature is central when performing Environmental Risk Assessments.
- **EINECS number**[491]
  A publicly available databases containing about 100,00 Numbers of existing commercial substances called EINECS (European Inventory of Existing Commercial Substances) Numbers under European Community Commission Decision 81/437/EEC. All of these numbers have the form XXX-XXX-X where X = a digit, e.g. 204-696-9 (for carbon dioxide).
- **IUPAC Name**[492]
  IUPAC (International Union of Pure and Applied Chemistry) is an authority on chemical nomenclature, terminology, standardised methods for measurement, atomic weights and many other critically evaluated data. An IUPAC Name might be carbon dioxide, for example.
- **IUCLID Long Name**[493]
  IUCLID Long name is a descriptive name of the substance, e.g. carbon dioxide. IUCLID (International Uniform Chemical Information Database) has been developed by the Joint Research Centre, European Commission, European Chemicals Bureau, 2001 and is publicly available.
- **IUCLID Molecular formula**[494]
  IUCLID Molecule formula e.g. CO2 has been developed by the Joint Research Centre, European Commission, European Chemicals Bureau, 2001 and is publicly available.
- **Material nomenclatures provided by trade associations**
  Many trade associations have specific material nomenclatures to be used by member companies and their supply chains.

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[490] CAS, http://www.cas.org.
[491] ECB, *European Inventory of Existing Commercial Substances EINECS*, viewed at http://ecb.jrc.it/existing-chemicals and http://ecb.jrc.it/esis/esis.php?PGM=ein&DEPUIS=autre.
[492] International Union of Pure and Applied Chemistry http://www.iupac.org.
[493] European Chemicals Bureau, International Uniform Chemical Information Database, IUCLID, http://www.jrc.it.
[494] European Chemicals Bureau, International Uniform Chemical Information Database, IUCLID, http://www.jrc.it.

- **Company-specific material nomenclatures**
  Specific material nomenclatures are often used by companies to manage nomenclatures in a company or sector. These nomenclatures are developed by companies to suit their individual needs.
- **ISO standards**[495]
  There are ISO standards for materials, e.g. 1043-1:2000 named Plastics - Symbols and abbreviated terms - Part 1: Basic polymers and their particular characteristics and 1043-2:2000; Plastics - Symbols and abbreviated terms - Part 2: Fillers and reinforcing materials. All ISO standards can be ordered from the International Organisation for Standardisation - ISO.

3.1.2 Substance and product property databases:

- **Chemicals**[496]
  A database containing information on over 11,000 chemicals, with data on physical and chemical properties, potential hazards, handling, storage and transport. This database is updated annually.
- **The combined chemical dictionary**[497]
  A database holding information on chemicals; it includes descriptive and numerical data on chemical, physical and biological properties of compounds, systematic and common names of compounds, literature references, structure diagrams and their associated connection tables.
- **Gmelin**[498]
  A collection of structures, properties, and references to the literature in inorganic and organometallic chemistry. Includes all data from the Gmelin Handbook.
- **Flow analysis**[499]
  A database including descriptions of substances, manufacturing methods, use patterns and physical data. The flow analyses are part of Sweden's official statistics.

3.1.3 Databases for production and transport

3.1.3.1 EXAMPLES OF LCI DATABASES

- **EcoInvent**[500]
  Maintained and quality reviewed LCI data for Europe.
- **LCA@CPM**[501]
  Maintained and quality reviewed LCI data.
- **JEMAI**[502]
  Maintained and quality reviewed LCI data for Japan.

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495 International Organisation for Standardisation, ISO http://www.iso.org/.
496 Chemical substances, www.prevent.se.
497 ChemNetBase, http://www.chemnetbase.com and http://www.chemnetbase.com/scripts/ccdweb.exe.
498 GMELIN Handbook of Inorganic and Organometallic Chemistry, Main Series and Supplements, 1772-, MDL Information Systems GmbH.
499 Flow analysis, http://www.kemi.se/kemstat/floden/flodessok.cfm?lang=eng.
500 EcoInvent - http://www.ecoinvent.ch.
501 LCA@CPM - http://kakapo.imi.chalmers.se/nukes/index.html.

- **BUWAL**
  Maintained and quality reviewed LCI data.
- **IISI**
  Maintained and quality reviewed LCI data.

3.1.3.2 EXAMPLES OF DATABASES CONTAINING DATA ON THE ENVIRONMENTAL LOAD CAUSED BY TRANSPORT

- **Emission Calculation tool provided by Schenker**[503]
  Data on European transport by Schenker Logistics.
- **NTMCalc**[504]
  Data on emissions and energy consumption for goods transport. Transport modes can be combined to form a transport chain.
- **ECOTransIT**[505]
  Comparative analysis of transport.
  SAS Emission calculator[506]
  Data on emission from airplane transport.

3.1.4 Scenarios, market, use and EOL

3.1.4.1 EXAMPLES OF DATABASES ON EOL

- **United States Geological Survey: "Commodity Statistics and Information" online database**[507]
  Statistics and information on the worldwide supply of, demand for and flow of minerals and materials, including recycling rates.
- **International Iron & Steel Institute: "World steel in figures" online publication** [508]
  Statistics on global production, consumption, supply, trade and recycling of iron and steel.
- **European Topic Centre on Waste and Material Flow: "Waste base" electronic database**[509]
  Data on waste and waste management in Europe, including waste quantities, policies, plans, strategies, and instruments.

3.1.4.2 EXAMPLES OF DATA ON ECONOMIC VALUE OF MATERIALS

- **London Metal Exchange**[510]
  Daily updated, transparent and maintained data on current prices and future price movements of non-ferrous metals.

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502 JEMAI - http://www.jemai.or.jp/english/index.cfm.
503 Emission Calculation tool provided by Schenker - http://www.btl.se/schenker_btl/about/environment/english/calculation.html.
504 NTMCalc - http://www.ntm.a.se/ntmcalc.
505 ECOTransIT - http://www.ecotransit.org/bin/query.exe/en?L=vs_greencargo&
506 SAS Emission calculator - http://www.sasems.port.se.
507 http://minerals.usgs.gov/minerals/pubs/commodity.
508 http://www.worldsteel.org.
509 http://waste.eionet.eu.int/etcwmf.
510 London Metal Exchange - http://www.lme.co.uk.

- **New York Mercantile Exchange**[511]
  Daily updated, transparent and maintained data on current and future prices of energy and metals such as gold, silver, copper, aluminium and platinum.
- **Metal Bulletin**[512]
  Transparent and maintained data on current prices of ferrous and non-ferrous metals.

3.1.4.3 EXAMPLES OF SCENARIO DATABASES

- **Institute for Prospective Technological Studies (IPTS)**[513]
  The mission of the IPTS is to provide technical/economic analysis to support European decision makers.
- **World Future Society (WFS)**[514]
  A non-profit educational and scientific organisation for people interested in how social and technological developments are shaping the future.
- **Institute for the Future (IFTF)**[515]
  An independent, non-profit research firm specialising in long-term forecasting, alternative futures scenarios, and the impacts of new products and next-generation technologies on society and business.

3.1.5 Indicators

- **GRI and WBCSD**
  A number of core indicators were developed jointly by GRI and WBCSD[516]. The GRI indicators are divided into Core indicators and Additional indicators. Core indicators are general. Additional indicators are company-specific.
- **ISO 14031**[517]
  Indicators are divided into Management Performance Indicators (MPIs), Operational Performance Indicators (OPIs) and Environmental Condition Indicators (ECIs).
- **Swedish EPA**[518, 519]
  The Swedish Parliament has laid down 15 environmental quality objectives. These have in turn been broken down into interim targets for quantifiable indicators.

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511 New York Mercantile Exchange - http://www.nymex.com.
512 Metal Bulletin - http://www.metalbulletin.com.
513 http://www.jrc.es/home/index2.cfm.
514 http://www.wfs.org.
515 http://www.iftf.org.
516 Verfaillie H, Bidwell R (2000), *Measuring eco-efficiency - a guide to reporting company performance*, World Business Council for Sustainable Development, http://www.wbcsd.ch/web/publications/measuring_eco_efficiency.pdf.
517 International Organisation for Standardisation (1999), ISO 14031: Environmental management - Environmental performance evaluation – Guidelines.
518 http://www.internat.environ.se/index.php3?main=/documents/objectiv/objectiv.htm.
519 Miljömålsrådet, http://www.miljomal.nu.

3.1.6 Change and sensitivity models

3.1.6.1 EXAMPLES OF DATA SOURCES FOR CHARACTERISATION MODELS

- **EcoIndicator 99**[520]
  Characterisation and weighting method developed in the Netherlands. Weighting is based on results from an expert panel.
- **EDIP**[521, 522]
  Characterisation and weighting method developed in Denmark. Weighting is based on distance to national targets.
- **EPS2000**[523]
  Characterisation and weighting method developed in Sweden. Weighting is based on surveys and interviews with people in the OECD countries about their willingness to pay (WTP) to avoid certain environmental impacts.
- **TRACI**[524]
  Characterisation method developed by the US Environmental Protection Agency.
- **WWLCAW**[525]
  Web-based LCA software tool containing uniform documentation on several characterisation models.

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520 Goedkoop, Spriensma (2000), The Eco-indicator 99: A damage oriented method for Life Cycle Impact Assessment Methodology Report, Second edition.

521 Hauschild, Wenzel and Alting (1997), Environmental assessment of products Vol. 1 Methodology, tools and case studies in product development, London Chapman & Hall.

522 Hauschild, Wenzel (1998), Environmental assessment of products Vol. 2 Scientific background, London Chapman & Hall.

523 Steen B (1999), A systematic approach to environmental priority strategies in product development (EPS). Version 2000 – Models and data of the default method, CPM report 1999:5, Chalmers University of Technology, Sweden.

524 US EPA, http://epa.gov/ORD/NRMRL/std/sab/iam_traci.htm.

525 WWLCAW, http://workshop.imi.chalmers.se/.

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EcoInvent, http://www.ecoinvent.ch

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Establishing common primary data for environmental overview of product life cycles

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Environmental problems today are highly connected to our consumption of products and services. Access to life cycle-based information on products' environmental impact helps to make sure that measures are taken where they will provide the most benefit. Information is necessary in order to help prevent environmental problems shifting from one phase of the life cycle to another.

This report describes how information about the environmental performance of products over their life cycles can be accessed anywhere and by any stakeholder throughout a product's life cycle.

The report covers different users of information, various methods and tools used to produce and disseminate that information, and primary data needed for those methods and tools. The report also outlines an information system organisation for potential use as a cooperative approach to supporting stakeholders of product life cycles with environmental information.

In 2004 the Swedish Environmental Protection Agency got a commission from the Government to develop information on the environmental impact of products. The aim of the commission was to develop the provision of data, knowledge and information of the environmental impact of products during the whole life cycle. This report is one of the basis to the report to the Government on the commission "Information om produkters miljöbelastning" Swedish EPA report no 5526.

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