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# The International Reference Life Cycle Data System (ILCD) Handbook

*Towards more sustainable production and consumption for a resource-efficient Europe*

**Marc-Andree Wolf, Rana Pant, Kirana Chomkhamsri, Serenella Sala, David Pennington**

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**European Commission**
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*Institute for Environment and Sustainability*

**Contact information**
European Platform on LCA
JRC – IES
Address: Joint Research Centre • Via Enrico Fermi 2749 • 21027 Ispra (VA) • Italy
E-mail: lca@jrc.ec.europa.eu
IES Communication Office: ies-contact@jrc.ec.europa.eu

http://ies.jrc.ec.europa.eu
http://www.jrc.ec.europa.eu

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# ACRONYMS

API – Application Programming Interface
BEUC[1] – The European Consumers' Organisation
BP X – Repository of good practices of French standardisation organisation
CDM[2] – Clean Development Mechanism
CEN[3] – European Committee for Standardisation (Comité Européen de Normalisation)
EEB[4] – European Environmental Bureau
ELCD – European Reference Life Cycle Database
EMAS – Eco-Management and Audit Scheme
EPA – Environmental Protection Agency
EMS – Environmental Management System
EPD – Environmental Product Declaration
ErP – Energy-related Products
ETV[5] – Environmental Technology Verification
EuP – Energy-using Products
FAO – Food and Agriculture Organisation of the United Nations[6]
FZK-IAI – Forschungszentrum Karlsruhe, Institut für Angewandte Informatik (see KIT-IAI)
GPP – Green Public Procurement (can also refer to Green Private Procurement in a broader context)
IBICT[7] – Instituto Brasileiro de Informação em Ciência e Tecnologia (Brazilian Institute of Information on Science and Technology), under the Brazilian Ministry of Science and Technology
ILCD – International Reference Life Cycle Data System
IPP – Integrated Product Policy
ISO – International Organisation for Standardisation
JEMAI[8] – Japan Environmental Management Association for Industry
JI – Joint Implementation
JRC RR – Joint Research Centre Reference Report
KEPI – Key Environmental Performance Indicators
KIT-IAI[9] – Karlsruhe Institute of Technology, Institute for Applied Computer Science (new organisational frame of the FZK-IAI since 2010)
LCA – Life Cycle Assessment
LCC – Life Cycle Costing
LCI – Life Cycle Inventory
LCIA – Life Cycle Impact Assessment
LCT – Life Cycle Thinking
MTEC[10] – National Metal and Materials Technology Center, under the Ministry of Science and Technology
NGO – Non-Governmental Organisation
PAS – Publicly Available Specification of British Standard

[1] www.beuc.org
[2] http://cdm.unfccc.int/index.html
[3] http://www.cen.eu/cen/pages/default.aspx
[4] http://www.eeb.org
[5] http://ec.europa.eu/environment/etv/index.htm
[6] http://www.fao.org
[7] www.ibict.br -
[8] www.jemai.or.jp/english/index.cfm
[9] http://www.iai.kit.edu/www-extern
[10] www.mtec.or.th/en/index.html

PCR – Product Category Rules
RE – Resource efficiency
SCP – Sustainable Consumption and Production
SETAC[11] – Society of Environmental Toxicology and Chemistry
SIP – Sustainable Industrial Policy
SME – Small and Medium Enterprises
SOC – Soil Organic Content
UNEP[12] – United Nations Environment Programme
UUID – Universally Unique Identifier
WBCSD[13] – World Business Council for Sustainable Development
WRI[14] – World Resources Institute

[11] www.setac.org
[12] www.unep.org
[13] www.wbcsd.org
[14] www.wri.org

# EXECUTIVE SUMMARY

## Overview

This **JRC Reference Report** provides an overview of the International Reference Life Cycle Data System (ILCD) Handbook. It describes the motivation for the Handbook, its development process and achievements, and it explains how to make best use of it. This report addresses:

- policy-makers and policy and scientific officers of public authorities,
- managers in industry and other stakeholders who are responsible for the development, implementation and monitoring of life cycle-related policies and strategies with an environmental component, and
- desk officers who commission service contracts and research and development projects on products, resources, waste and related technologies.

The **International Reference Life Cycle Data System (ILCD) Handbook** further specifies the broader provisions of the ISO 14040 and 14044 standards on environmental life cycle assessment (LCA). In a nutshell, it provides a basis for consistent, robust and quality-assured environmental LCA studies, as required in a policy and market context.

LCA and the ILCD Handbook focus on environmental issues. Through extensions, they equally facilitate coherent **sustainability assessments** that fully capture the economic and social implications via Life Cycle Costing and social LCA.

The first edition of the main set of **ILCD Handbook guidance documents was publicly launched in March 2010** by the Commissioner for the Environment Janez Potočnik.

## EU policy background

During the 1990s and even more so since 2000, new types of policies have been developed that take an integrated view of the environmental performance of products over their life cycle. However, the lack of authoritative guidance on LCA has often led to unnecessary divergences in results and recommendations. While LCA helped to make improved decisions, some limitations in consistency and quality assurance meant that it did not fully meet policy and market needs.

With the 2003 **Communication on Integrated Product Policy (COM(2003) 302)**, the European Commission set a milestone in the development of more specific life cycle-based policies and took action to provide the necessary authoritative guidance. The Commission committed itself to "*... produce a handbook ... on best practice, based on best possible consensus attainable among stakeholders*". The development of the ILCD Handbook was mandated. Its scope was subsequently broadened beyond products to fully support other life cycle-based policies as well.

Life cycle thinking is fundamental to, for example, the **Thematic Strategy on the Sustainable Use of Natural Resources (COM(2005) 670)** and the **Thematic Strategy on the Prevention and Recycling of Waste (COM(2005) 666)**, and is an important element of the **Waste Framework Directive (2008/98/EC)**. LCA studies serve to identify the ecolabelling criteria under the **EU Ecolabel Regulation (EC 66/2010)** and are used to properly capture indirect effects under the **EMAS III Regulation (EC 1221/2009)**.

Life cycle thinking is also of growing importance in the impact assessments used to assess policy options, as well as in the indicators used to monitor progress in sustainable production and consumption (e.g. via life cycle-based resource efficiency indicators).

The European Commission's **Sustainable Consumption and Production and Sustainable Industrial Policy Action Plan (COM(2008) 397)** integrates the above-mentioned policies and further strengthens the use of quantitative LCAs, reiterating the need for consistent and reliable methods and data.

The 2011 Communication on **A resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy (COM(2011) 21)** takes these developments to the next stage. This Communication promotes a life cycle approach to reduce the environmental impacts of resource use throughout the EU. This flagship Initiative highlights the importance of working with a consistent analytical approach. Moreover, in its conclusions of 20 December 2010[15], the Council of the European Union "*INVITES the Commission and Member States to continue their efforts to make European resources and materials use more sustainable throughout the life-cycle by: ... taking into account work done in the context of the ILCD...*".

## Industry and society background

**Industry** has used LCA since the late 1980s. Its use by **other stakeholders** (e.g. green NGOs, consumer rights NGOs) is more recent, but has greatly increased over the past few years.

LCA is helping companies and other stakeholders to make better-informed decisions and public communications. **LCA applications** can be used in ecolabelling, ecodesign, environmental and carbon footprinting, and waste management. LCA also successfully addresses strategic questions on the environmental impact of and potential for improvement in the use of natural resources. It is used in industry to steer the development of technology families (e.g. fuel cells) and to quantify the environmental performance of production sites and companies. Increasingly, LCA is also being used to evaluate the environmental impact of policy options for new or modified policies (i.e. in policy impact assessment).

## About LCA

LCA is a **scientific, structured and comprehensive method** that is internationally standardised in ISO 14040 and 14044. It quantifies resources consumed and emissions as well as the environmental and health impacts and resource depletion issues that are associated with any specific goods or services ('products'). It covers climate change, summer smog, ecotoxicity, human cancer effects, material and energy resource depletion, and so on. Crucially, it allows for direct comparison of products, technologies and so on based on the quantitative functional performance of the analysed alternatives.

LCA **captures the full life cycle** of the system being analysed: from the extraction of resources, through production, use and recycling, up to the disposal of remaining waste. Critically, LCA helps to avoid an unwanted 'shifting of burdens' whereby a reduction of environmental pressures at one point in the life cycle leads to an unwanted increase elsewhere in different locations and in the form of different environmental pressures. LCA helps to identify and avoid situations in which, for example, waste issues are created while improving production technologies, land is degraded while reducing greenhouse gas emissions, or toxic pressures are increased in one country while reduced in another.

LCA is therefore a vital and **powerful decision support tool** that complements other methods to help make our society more sustainable and resource-efficient.

## About the ILCD

The **ISO 14040 and 14044 standards** provide an important framework for LCA. This framework, however, leaves the individual expert with a range of important choices. These choices can negatively affect the reliability and comparability of the results of an assessment. Equally, the methodologies behind life cycle data from different sources can differ widely, so the data are often incompatible. No single data source can support all assessment needs. While flexibility is essential in responding to the large variety of questions addressed using LCA, further guidance is needed.

The **ILCD** has been developed to provide this guidance for greater consistency and quality assurance. The ILCD consists primarily of the ILCD Handbook and the ILCD Data Network that is now being prepared[16], plus a range of supporting documents and tools. This JRC Reference Report focuses on the ILCD Handbook.

## ILCD Handbook

The ILCD Handbook is the core of the ILCD. The ILCD Handbook is a series of technical documents that provide guidance for good practice for LCA in industry and government. It consists of the following documents:

- ILCD Handbook – General guide for Life Cycle Assessment – Detailed guidance,
- ILCD Handbook – General guide for Life Cycle Assessment – Provisions and Action Steps,

[15] Council Conclusions on sustainable materials management and sustainable production and consumption: key contribution to a resource-efficient Europe. 3061st Environment Council meeting. Brussels, 20 December 2010.

[16] The public launch of the ILCD Data Network is in preparation and expected in early 2012.

- ILCD Handbook – Specific guide for Life Cycle Inventory data sets,
- ILCD Handbook – Recommendations based on existing environmental impact assessment models and factors for Life Cycle Assessment in a European context,
- ILCD Handbook – Framework and requirements for Life Cycle Impact Assessment models and indicators,
- ILCD Handbook – Review schemes for Life Cycle Assessment,
- ILCD Handbook – Reviewer qualification for Life Cycle Inventory data sets,
- ILCD Handbook – Review scope, methods and documentation *(under development)*,
- ILCD Handbook – Nomenclature and other conventions,
- ILCD Handbook Terminology *(under development)*.

These documents provide the guidelines and background information to **cover all the steps necessary to perform any kind of LCA**.

The **guidance documents are differentiated in three ways**:

- firstly, for analysis and comparison of product options and other micro-level questions, including those arising at the company level;
- secondly, for policy/strategic studies and other macro-level questions;
- thirdly, for monitoring.

While being comprehensive and aiming to **improve reproducibility of data**, the ILCD Handbook has to be generic enough to maintain the **necessary flexibility** that would allow it to be fully applicable to any kind of system and issue. During the development of the '*handbook on good practice*', **theoretical exactness and comprehensive coverage** had to be balanced with **practicality and cost effectiveness** in broad-scale applications.

The ILCD Handbook serves moreover as a **'parent' document** that aids the development of application-specific, sector-specific and product group-specific guidance documents, criteria and related software tools. Such straightforward practice guides and tools are considered to be the most appropriate solutions for day-to-day use. They facilitate the use of LCA in small and medium-sized enterprises (SMEs) as well as simplify standard assessments in larger organisations. Specific guidance documents can be developed by any organisation. Once an independent review panel concludes that they meet the ILCD requirements, they complement the ILCD Handbook.

### Development and consultation

The development of the ILCD has been coordinated by the European Commission's Joint Research Centre (JRC) through its Institute for Environment and Sustainability (IES), together with the Directorate-General for the Environment's Directorate for Sustainable Development and Integration. Development started in mid-2005 and involved a broad and iterative international consultation process with experts, stakeholders and the public. This process is described in each guidance document. Coordination outside the European Union (EU) was considered to be particularly important, as product life cycles are increasingly global.

More technical information and access to the ILCD Handbook and all complementary and supporting developments are available at http://lct.jrc.ec.europa.eu

### The three target audiences of the three sections of this report

The **Executive Summary** targets policy-makers, policy and scientific officers of public authorities and upper management in industry and provides an overview for the general reader.

The **main body** of the report provides additional information for middle and lower management.

The **Annexes** provide further details, including suggested formulations for desk officers on how to utilise the ILCD Handbook in their domains.

# 1. POLICY AND INDUSTRY BACKGROUND

## 1.1 European Union policies

### *1.1.1 The path to life cycle-related environmental policies*

**Environmental policies of the 1970s and 1980s** typically had a very specific focus, such as limiting single emissions of highly toxic substances or ruling on specific waste streams. Legislation evolved that banned the use of specific substances in products. Many of these policies are still in effect. They remain key for setting minimum environmental requirements for industry, governments and private households. However, they have inherent limitations – for example, they cannot avoid the shifting of burdens among different environmental impacts or to other countries via imported products. Moreover, they cannot prevent the unwanted transfer of impacts across the life cycle stages of products, for example the adoption of 'greener' production if it leads to greater impacts during the product's use or end-of-life, or vice versa.

**During the 1990s**, other types of environmental policies were developed in many countries, which have either complemented or replaced the former policies. Along with toxic and acidifying emissions, these policies consider other pressures such as greenhouse gases. Also, cross-media effects of emissions to air, water and soil are better captured and the initial single-substance approaches have been further developed to include a broader set of pressures and impact-related environmental indicators. These indicators integrate, for example, the various individual greenhouse gases into one greenhouse gas indicator, thereby providing both more comprehensive and more condensed information.

**Since about 2000**, the principle of life cycle thinking (LCT) has been increasingly integrated into a number of new policy instruments. These new policies either add life cycle elements, only slightly modifying existing policies often through caveats such as "unless resulting in an increase in environmental burden", or they fundamentally incorporate the life cycle approach and adopt an integrated overview of the environmental performance. This latter approach allows assessment of the entire life cycle of products, technology options and policy strategies, or of production sites and companies. LCT helps to avoid the above-mentioned unwanted shifting of burdens and thereby helps to steer society more effectively towards resource-efficient production and consumption.

These modern life cycle-based policies and instruments require support in the form of dedicated scientific and technical guidance – for better reproducibility and for more reliable decision-making. This requirement is the driving force behind the development of the ILCD Handbook.

### *1.1.2 Life cycle-related European policies*

With the Communication on **Integrated Product Policy** (IPP) (COM(2003) 302), the European Commission has set a milestone in the development of life cycle-based policies and has highlighted the need for a knowledge base to support such policy approaches. In the IPP Communication it was acknowledged that "LCAs [Life Cycle Assessments] provide the best framework for assessing the potential environmental impacts of products currently available". It has, however, also been stated that "*... the debate is ongoing about good practice ...*". The Commission has therefore committed to "*... produce a handbook ... on best practice, based on the best possible consensus attainable among stakeholders*". The **development of the ILCD Handbook** was initiated under this mandate. It has been extended to also facilitate other life cycle-related policies[17]. Figure 1 illustrates how life cycle-related policy

[17] See also SEC(2009)1707 final – Commission staff working document accompanying the Report from the Commission to the Council, the European Parliament, the European and Social Committee and the Committee of the Regions on the State of Implementation of Integrated Product Policy (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2009:1707:FIN:EN:PDF).

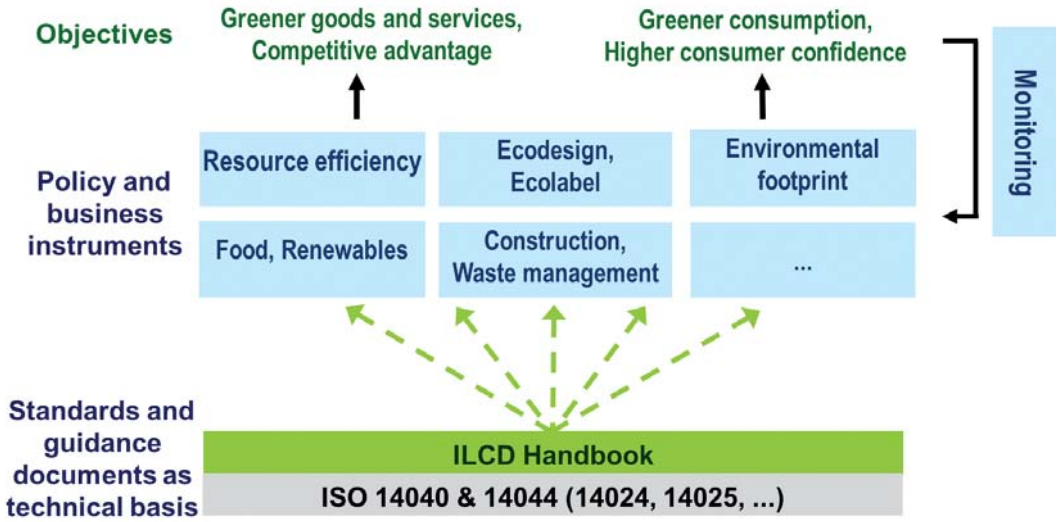


*Figure 1: Strengthening coherence of life cycle-based policy and business instruments by building on a common technical and methodological basis.*

and business instruments can use the ILCD Handbook for consistent life cycle guidance towards achieving overall objectives in a coherent manner.

In a follow-up to the IPP Communication, the **Sustainable Consumption and Production and Sustainable Industrial Policy (SCP/SIP) Action Plan** (COM(2008) 397) stressed the importance of the underlying knowledge base. The Action Plan emphasised that "*... consistent and reliable data and methods are required to assess the overall environmental performance of products ...*". Product legislation was regarded as one important aspect in need of improvement since "*Most product legislation addresses only specific aspects of a product's life cycle*". The SCP/SIP Action Plan integrates a number of life cycle-related policies and more specific instruments under one umbrella, further strengthening them.

These **policies and instruments at the EU level** include:

- Ecodesign Directive (2005/32/EC) on energy-using products and the amended/recast Ecodesign Directive 2009/125/EC on energy-related products;
- EU Ecolabel Regulation (EC 66/2010) on a revised Community ecolabel award scheme;
- Eco-Management and Audit Scheme (EMAS) III Regulation: (EC 1221/2009) allowing voluntary participation by organisations in a Community eco-management and audit scheme;
- Communication on Green Public Procurement (GPP) (Public procurement for a better environment (COM (2008) 400));
- Environmental Technology Verification scheme (ETV).

The SCP/SIP Action Plan relates to further policies and issues such as the reduction of the use of hazardous materials and of rare resources, and includes the outlook for further improving resource efficiency. It also explicitly refers to the Thematic Strategy on the Sustainable Use of Natural Resources (COM(2005) 670), the Energy Labelling Directive (now recast as the Directive on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products (2010/30/EU)), and related specific Directives on various household appliances, as well as the Energy Star: Regulation (EC) No 106/2008 of 15 January 2008 on a Community energy-efficiency labelling programme for office equipment.

There are a number of life cycle-based or related European policies that deal with specific product groups and specific aspects, typically focusing on specific life cycle stages. Among these, one of the strongest references to life cycle thinking (LCT) is made in the **Thematic Strategy on the Prevention and Recycling of Waste (COM(2005) 666)**. This policy document states that: "*All phases in a resource's life cycle need to be taken into account as there can be trade-offs between different phases and measures adopted to reduce environmental impact in one phase can increase the impact in another. Clearly, environmental policy needs to ensure that negative environmental impact is minimised throughout the entire life cycle of resources. By applying the life-cycle approach, priorities can be identified more easily and policies can be targeted more effectively so that the maximum benefit for the environment is achieved relative to the effort expended. The life-cycle approach will be incorporated in*

*EU legislation by clarifying the objectives of the Waste Framework Directive so that they explicitly consider the life-cycle perspective." Accordingly, "EU waste policy should aim to reduce the negative environmental impact of waste generation and management and to contribute to an overall reduction of the environmental impact of the use of resources.*" The 2011 report from the Commission on the Thematic Strategy on the Prevention and Recycling of Waste (COM(2011) 13 final) refers to the JRC-run European Platform on LCA as a contribution to providing LCT and assessment expertise. The accompanying Commission staff working document mentions the ILCD Handbook as providing detailed guidance for LCA.

**Directive 2008/98/EC on waste and repealing certain directives** identifies the need to strengthen LCT in the Waste Framework Directive 2006/12/EC and specifies: "*When applying the waste hierarchy referred to in paragraph 1, Member States shall take measures to encourage the options that deliver the best overall environmental outcome. This may require specific waste streams departing from the hierarchy where this is justified by life-cycle thinking on the overall impacts of the generation and management of such waste.*"

Two of the seven **Europe 2020 Flagship Initiatives** address 'sustainable growth'[18] and have a strong life cycle component. Firstly, the **Communication on an Integrated Industrial Policy for the Globalisation Era (COM(2010) 614)** announces that: "*The Commission will work on a common European methodology for assessing environmental impacts associated with consumer products, based on life-cycle analysis and objective criteria.*" The second relevant document is the **Communication on a resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy (COM(2011) 21 final)**, which aims to cover from a life cycle perspective all natural resources ranging from materials, energy and land resources to air, water and soil as sinks for emissions. It states that: "*Resource-efficiency policies need to address appropriately trade-offs. In order to make the right choices both now and for the longer term, we need to consider the whole life-cycle of the way we use resources, including the value chain, and the trade-offs between different priorities.*" The aim – as in the Thematic Strategy on the Sustainable Use of Natural Resources – is to "*limit the environmental impact of resource use*", as opposed to just reducing the amount/mass of resources used. Importantly, the transfer of environmental pressures abroad via imported products and other shifting of burdens (i.e. among life cycle stages and among different environmental and resource problems) are explicitly named and examples are given, so helping resource efficiency policies to be more effective. Finally, a direct link is made to the use of life cycle information in policy impact assessment: "*Building up the knowledge base will also require further work to evaluate policies and collect life-cycle data to further develop policies and prepare impact assessments … In this context, it will also be needed to develop more harmonised and transparent ways of measuring environmental impacts*." This was supported and strengthened by industry during the related stakeholder consultation in March and April 2011[19]: "Businesses called for the development of a sound knowledge base, more policy coherence, indicators to measure progress and the application of a full life cycle perspective."

**Monitoring resource efficiency and beyond GDP Communication:** In the context of resource efficiency in Europe, new approaches have been developed by the Commission services for measuring and monitoring the overall environmental impact of nations with life cycle-based resource efficiency indicators[20], including the impacts related to imported and exported products.

**Member States as drivers of developments at the EU level**: Life cycle-based policy developments at the EU level are very much driven by national developments and the needs of individual Member States. Two examples related to the ILCD Handbook include:

- The British 'PAS 2050: Specification for the assessment of the life cycle greenhouse gas emissions of goods and services' has driven the development of product carbon footprinting;
- The French Grenelle 2 legislation includes the development of environmental life cycle information for mass-market products (ADEME/AFNOR BP X 30-323 methodology), which includes other environmental impacts

[18] http://ec.europa.eu/europe2020/priorities/sustainable-growth/index_en.htm

[19] Commission staff working paper SEC(2011) 1067 final.

[20] See http://lct.jrc.ec.europa.eu/assessment/projects#a. This development started from the Thematic Strategy on the Sustainable Use of Natural Resources (COM(2005) 670) and is referred to in the GDP and beyond Communication (COM(2009) 433 final): *"The Commission will also continue to work on indicators that capture the environmental impact outside the territory of the EU (e.g. indicators to monitor the Thematic Strategy on the Sustainable Use of Natural Resources) …"*.

beyond the carbon footprint. It was tested in 2011 and marks an important step in better informing consumers about the overall life cycle impacts of products.

These and other developments by Member State governments, private actors and in public-private partnerships worldwide have paved the way towards the development at the European level of a methodology for the European environmental footprint of products[21] and corporate environmental disclosure[22].

## 1.2 The global policy perspective

The Communication on a resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy (COM(2011) 21 final) addresses the global dimension of Europe's efforts towards resource efficiency. It starts with the following observation: "*Given the global dimension of key environmental issues such as climate change, biodiversity, land use, deforestation, external impacts of consumption and production patterns, competitiveness, security of supply and access, the EU needs to address resource efficiency issues internationally and to cooperate closely with key partners ...*".

EU product supply chains extend widely to countries outside of the European Union. It is therefore **essential to take an international perspective** to make sure that the complete life cycle of products can be modelled in a consistent way. Life cycle-based policies are being developed in a growing number of countries worldwide. It is therefore increasingly important that life cycle methods are internationally coordinated between different governments/organisations and that more fit-for-purpose, consistent and quality-assured data are made available.

The following gives a limited indication of some of these activities and policies to illustrate the relevance of the topic in countries outside the EU:

In **Brazil**, the modern 2010 Policy for Solid Waste Management (Política Nacional de Resíduos Sólidos, PL 203/1991 (PNRS)) includes a life cycle approach as one of its guiding principles[23]. Moreover, the Roadmap for Industrial Development highlights the need for life cycle management in Brazilian companies.

In **China**, the key national policies on Energy-using Products, the Waste Electrical and Electronic Equipment Directive and the Restriction of Hazardous Substances are based on LCT.

In **Japan**, the legislation on Promoting Green Purchasing and the legislation for the Promotion of the Effective Utilisation of Resources (the latter also known as '3 Rs – reduce, reuse and recycle') are key life cycle-based policies. The recent launch of the Japanese carbon-footprint labelling scheme with a strong and wide buy-in of industry is another important life cycle-based instrument.

In **Switzerland**, life cycle-related legislation includes the application of reduced taxes since 2008 to renewable fuels which demonstrate that they meet minimum requirements in their overall environmental life cycle performance (Mineralölsteuerverordnung 641.611 of 20 November 1996, amended as of 1 July 2008)[24].

In **Thailand**, the GPP policy is a major driver for national LCA data development. This is complemented by Thailand's recent carbon-footprint programme.

In the **United States of America**, several governmental programmes apply LCA. These include the US Environmental Protection Agency's Environmentally Preferable Purchasing Program, the Renewable Fuel Standard Program, and state-level legislation such as the implementation of the Californian Low Carbon Fuel Standard of 2007.

Similarly, in other countries such as **Australia, Canada, Malaysia, Mexico, New Zealand and South Korea**, life cycle approaches are politically relevant, often driven by national and international ecolabelling schemes, carbon-footprint labels, Environmental Product Declarations (EPD), GPP and ecodesign activities, or from various other resource protection and solid waste management considerations.

To help implement the above-mentioned policies, national life cycle inventory (LCI) databases of key goods and services have been or are currently being developed in all of the respective countries. Similarly, the European Reference Life Cycle Database (ELCD) has been developed by the European Commission in close co-operation with European industry[25].

[21] http://ec.europa.eu/environment/eussd/product_footprint.htm
[22] http://ec.europa.eu/environment/eussd/corporate_footprint.htm
[23] http://www.camara.gov.br/sileg/prop_detalhe.asp?id=15158
[24] http://www.admin.ch/ch/d/sr/6/641.611.de.pdf
[25] ELCD database at http://lct.jrc.ec.europa.eu/assessment/data

International organisations, such as the United Nations Environment Programme **(UNEP)** and the Food and Agriculture Organisation **(FAO)**, are increasingly playing an important role in LCA, bringing together different stakeholders in relation to methodological issues as well as providing a service for the intergovernmental coordination of activities[26].

## 1.3 Industry and other stakeholders

### *Industry*

Industry has used LCA **since at least the late 1980s**, with some companies starting as far back as the 1970s. Initially, it was mostly large companies in leading economies that used LCA – in isolated projects.

This situation changed over time: due to co-operation along the **supply chain** and as a consequence of stakeholder and consumer demands, LCA is applied in a large number of sectors, including by some SMEs. Equally, the number of countries in which LCA is used by at least some companies has increased substantially over the past decades.

Nowadays, more and more larger companies have **in-house experts or expert teams** on LCA and the approach is often integrated with product development. It can be assumed that a substantial or even dominant part of LCA activities are carried out in or on behalf of industry for internal decision support and the studies are never published. Such activities help to better inform decision-making in these companies. This includes increasing awareness of activities and their impacts on supply chains, use and end-of-life phases.

LCA is also being increasingly used at the **association level**, especially in the form of database development[27] and sector/product-specific guidance. Examples include the activities of the European Retail Forum[28], the European Food Sustainable Consumption and Production (SCP) Round Table[29], and industry declarations and publications expressing a preference for life cycle-based decision support[30].

The **range of applications of LCA** in industry has also been extended. Initially, the main purpose was typically to gain a better understanding of the companies' supply chains and to obtain quantitative information on product-related implications in the context of a general preparedness. These days, LCA is used to inform and influence specific product decisions. It is increasingly being applied to assess and compare strategic alternatives with respect to, for example, raw materials (e.g. 'bio-based society') and technologies (such as diesel vs. petrol engines vs. fuel cells). LCA is also employed to capture and monitor corporate environmental performance (e.g. to capture indirect effects in the Eco-Management and Audit Scheme).

In short, LCA helps companies to identify the best environmental options by quantifying environmental impacts, benefits and trade-offs. LCA – while it cannot replace the decision-making process – supports decision-makers in making better informed choices.

[26] Coordinated at UNEP's DTIE Division in Paris, see http://www.unep.org/dtie

[27] Examples include the LCI databases developed by the following associations and published via the European Reference Life Cycle Database (ELCD) coordinated by the JRC-IES: Alliance for Beverage Cartons and the Environment (ACE), Association of Plastics Manufacturers (PlasticsEurope), Confederation of European Waste-to-Energy Plants (CEWEP), European Aluminium Association (EAA), European Cement Association (CEMBUREAU), European Confederation of Iron and Steel Industries (EUROFER), European Copper Institute (ECI), European Federation of Corrugated Board Manufacturers (FEFCO), Industrial Minerals Association Europe (IMA-Europe), International Zinc Association (IZA), Lead Development Association International (LDAI), Sustainable Landfill Foundation (SLF) and The Voice of the European Gypsum Industry (EUROGYPSUM). Others are preparing to provide data: European Automobile Manufacturers' Association (ACEA), European Confederation of Woodworking Industries (CEI-Bois), European Fertilizer Manufacturers Association (EFMA), European Container Glass Federation (FEVE), Technical Association of the European Natural Gas Industry (Marcogaz) and Tiles & Bricks Europe (TBE).

[28] The European Retail Forum has published an issue paper on LCA (see http://ec.europa.eu/environment/industry/retail/index_en.htm).

[29] The European Food SCP Round Table has published a 'Guiding Principles' document, which is a voluntary agreement of 20 associations related to food and drink supply chains to adopt LCA principles (see http://www.food-scp.eu/files/Guiding_Principles.pdf).

[30] See for example 'A Global Language for Packaging and Sustainability' by the Global Packaging Initiative (http://www.vics.org/docs/KSurvey/press_releases/pdf/GPP_FinalReport_170610.pdf).

### *Market context, other stakeholders*

**LCA is increasingly being used in a market context**, i.e. in communication of industry to business customers (e.g. via published EPDs), to consumers (as evidenced via the growing set of life cycle-based carbon-footprint labels), and to authorities (e.g. in the context of stakeholder consultations on policy developments and of developing environmental product labels).

A number of **green and consumer NGOs** increasingly make use of LCT and promote its use for policy decision support. Examples include publications and stakeholder input prepared by the European Environmental Bureau (EEB) as an umbrella organisation of many European green NGOs and the European Consumers' Organisation (BEUC) as an umbrella organisation of many European consumer rights NGOs[31].

[31] See for example paper criteria for the EU Ecolabel – EEB and BEUC comments after the 4th Working Group Meeting (13.04.2010) (http://www.eeb.org/?LinkServID=3E527DB4-A82A-388D-BD8B7F465763CE33&showMeta=0) and other consultation input at www.eeb.org

# 2. INTRODUCTION TO LIFE CYCLE ASSESSMENT

## 2.1 (Environmental) Life Cycle Assessment[32]

Over their lifetime, products (goods and services) not only serve valuable functions but they also contribute to various environmental pressures and the depletion of resources. The LCA method was originally developed to help quantify these pressures and related impacts by analysing the resources extracted and the emissions related to a product over its entire life cycle.

The strength of LCA lies in the unique combination of its **five principles**:

- Firstly, LCA brings a **wide range of environmental problems** into an integrated assessment framework. These problems include climate change, toxic effects on humans and ecosystems, summer smog, material and land resource depletion. This helps to avoid the unwanted shifting of burdens, whereby reducing one kind of impact leads to an increase in another.

- Secondly, it captures these problems in a **scientific and quantitative** manner. By inventorying the amount of all the related resource uses and emissions, it allows for the relative and absolute analysis and monitoring of achievements over time. Subjective elements can largely be excluded or made transparent and systematically addressed in the interpretation of results.

- The third principle is that LCA allows the environmental pressures and impact potentials to be **related to any defined system**, such as a particular type of goods, a service, a company, a technology strategy, a country, etc.

- According to the fourth principle, LCA integrates the resource use and emissions over the **entire life cycle** of the analysed system, from the extraction of natural resources through material processing, manufacturing, distribution and use, up to recycling/energy valorisation and the disposal of any remaining waste. This helps to avoid resolving one environmental problem (e.g. during production) while creating others (e.g. during use or end-of-life treatment).

- The fifth principle of LCA is that it facilitates comparisons of the environmental performance of different systems/options on an **equal basis** and helps to identify areas for improvement. It ensures a level playing field. This is achieved by comparing alternative options strictly on the basis of their 'functional unit', i.e. their technical performance/equivalence. The functional unit is the precise quantitative description of the function(s) provided by the analysed system, i.e. "what" does it do, "how much" function does it provide, and "how well" and "for how long" does it do this. In comparisons that do not consider this functional unit, a product or a technology that delivers fewer functions or worse functions compared to its competitor may wrongly appear to be better environmentally.

Adhering to these principles, a specific LCA study is tailored to address the question it is meant to answer.

This **smart approach** allows for a science-based, quantitative comparison of alternatives. It captures the relevant environmental impacts and quantitatively considers trade-offs both among different impacts and of impacts occurring at different stages of the life cycle. See Figure 2.

[32] See also the following non-technical introductory brochures on LCA and its uses in industry and policy:
- EC, DG JRC and DG ENV (2010): Making Sustainable Consumption and Production a Reality – A guide for business and policy makers to Life Cycle Thinking and Assessment (http://lct.jrc.ec.europa.eu/assessment/publications).
- UNEP and SETAC (2009): Life Cycle Management – How business uses it to decrease footprint, create opportunities and make value chains more sustainable. (http://www.unep.fr/shared/publications/pdf/DTIx1208xPA-LifeCycleApproach-Howbusinessusesit.pdf).

### The phases of an LCA (adapted from ISO 14044, ILCD Handbook)

An LCA comprises **five main phases**: goal definition, scope definition, inventory analysis, impact assessment and interpretation. This is **complemented by reporting and review**. The following text outlines these five phases without going into details.

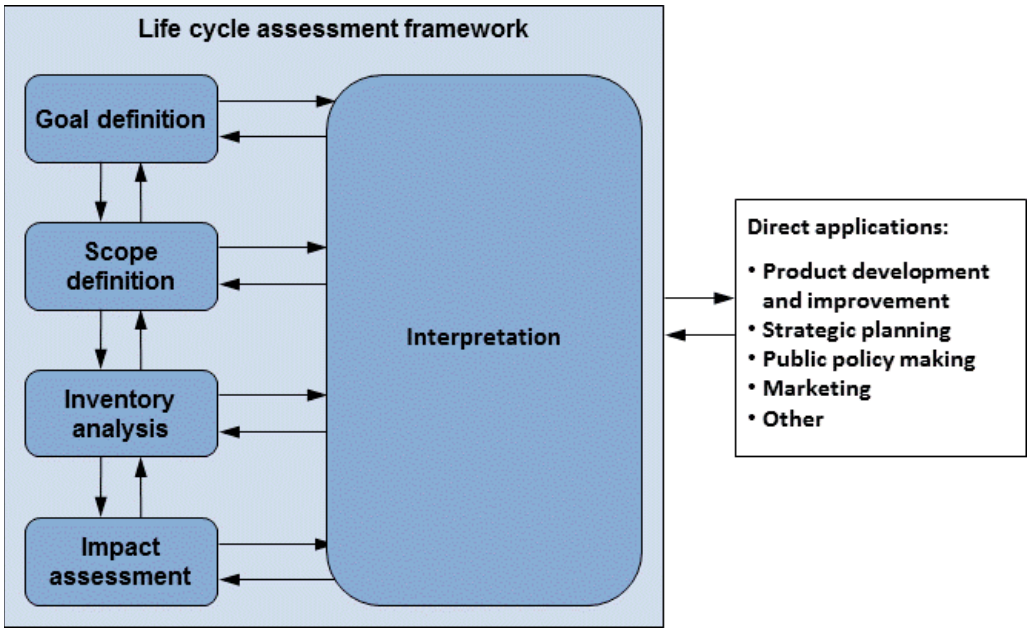


*Figure 3: Framework for LCA (from ISO 14040:2006; modified).*

The **goal definition** includes identifying the decision context, the intended applications and the intended audience of the study. It also needs to be clarified whether the study includes any comparative statements that will be published, e.g. that one product would be better (or equal) to another product. If so, other parties that may be affected by these comparisons should also be involved.

The **scope definition** includes clearly describing the following items, in line with the study goal: the system to be studied (e.g. a specific brand), the functions of the system, the functional unit that will be compared as the basis for a fair comparison, the life cycle stages to be covered, the environmental impacts to be investigated, the LCIA methods to be applied, the interpretation approaches to be used, the assumptions made about data and method issues, value choices, limitations, data quality requirements, type of critical review if any, and the type and format of the report required for the study.

The **Life Cycle Inventory (LCI) analysis** mainly includes the collection of data on resource use and emissions for the 'foreground' process steps (e.g. manufacturing and packaging of a product), and the actual modelling of the life cycle of the analysed system. This includes the use of background life cycle data (e.g. data sets on electricity and materials purchased, or on downstream processes such as recycling). A first validation of data is carried out in this phase.

The **Life Cycle Impact Assessment (LCIA)** phase includes the assignment of the LCI results to the selected impact categories and the calculation of the potential environmental impacts in each category such as climate change, acidification, human health, aquatic eco-toxicity, material resource depletion, land use, etc.

The **interpretation** phase starts with the identification of significant issues (e.g. the main processes and resources/emissions that quantitatively contribute most to the results). This is carried out based on the results of the LCI and LCIA phases of the study. The interpretation includes completeness, sensitivity and consistency checks, and addresses the uncertainty and accuracy of the results. If foreseen as part of the study's goal, conclusions are drawn – highlighting any limitations – and recommendations are derived.

While these five phases have a clear order, **LCA studies are iterative**. This allows efforts to be focused on those processes, resources and emissions that are most relevant to the analysed case: based on initially available data and in view of the accuracy and precision necessary to answer the question posed in the study, one to three iterations are typically carried out before the final results are arrived at.

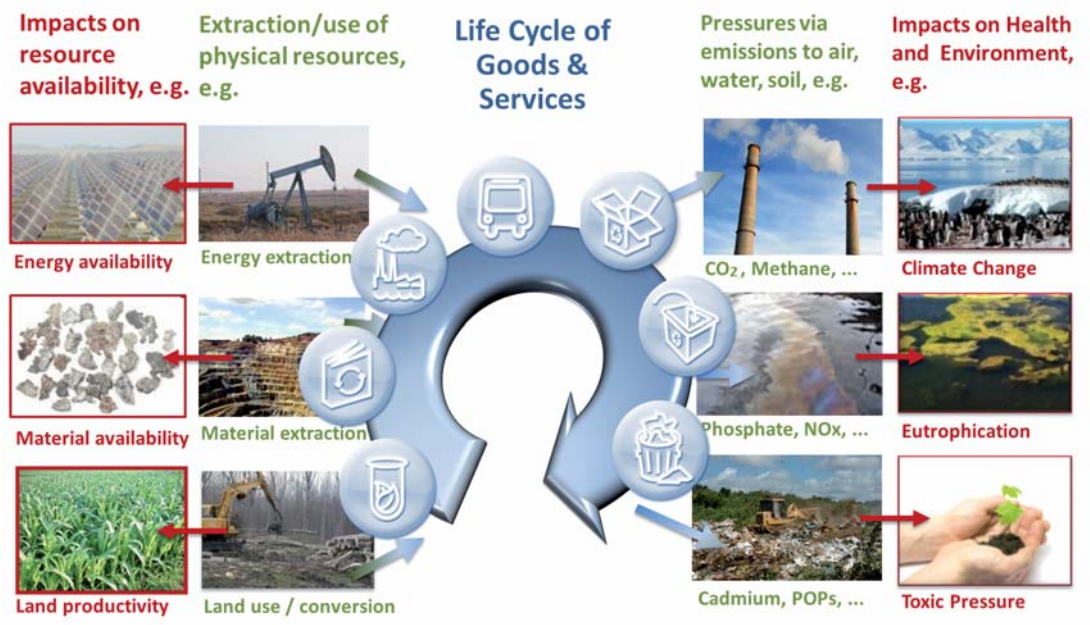


*Figure 2: Schematic representation of the life cycle of products showing how material, energy and land resources are consumed and environmental impacts are caused by emissions and resource use.*

## 2.2 Standardisation of LCA

A first Code of Practice in LCA was developed by working groups of the Society of Environmental Toxicology and Chemistry (SETAC) in the early 1990s.

The importance of LCA was further reinforced by international standardisation through the **ISO 14040 series** in 1997, with the latest revision in 2006 resulting in the two core standards ISO 14040 and 14044. A range of other ISO standards draws on the 14040 series standards: ISO 14020:2000 (Environmental labels and declarations – General principles), ISO 14021:1999 (Environmental labels and declarations – Self-declared environmental claims (Type II environmental labelling)), ISO 14024:1999 (Environmental labels and declarations – Type I environmental labelling – Principles and procedures), ISO 14025:2006 (Environmental labels and declarations – Type III environmental declarations – Principles and procedures) and ISO 14067 (draft) on carbon footprinting.

The ISO 14040 and 14044 standards are the starting point for the ILCD Handbook. It is expected that the ILCD Handbook will feed back into the standardisation, both on a general level and as a reference for product- or sector-specific standardisation mandates.

The box on the previous page provides some more technical details on the phases of an LCA study.

## 2.3 Limitations of (environmental) LCA

Environmental LCA has several limitations, so it must be complemented by other methods and instruments, depending on the specific question to be answered and the relevance of the limitations for the given case.

Firstly, LCA only captures those **pressures that act via the environment**, i.e. emissions to nature and resource use/extraction from nature. It does not include the direct effect of products on humans, such as the potential health effects of the application of beauty and personal hygiene products, of medicine, and of food itself (LCA only covers the intake of environmental pollutants via food). Such health effects are addressed by risk assessment methods that currently complement LCA – systematically integrated approaches are not yet available. In addition, indoor and workplace emissions are not yet part of most LCAs, but approaches and impact factors are being developed within the LCA framework to capture these impacts.

Secondly, LCA relates to the **regular production, use and end-of-life** management of products and processes, i.e. it does not cover accidents. Complementary life cycle-based accident assessment approaches are under development.

**Other instruments**, while they may address the same systems/products, are **complementary to the purpose and objectives of LCA**.

Examples are chemical risk assessments that are applied for regulatory threshold purposes and Environmental Impact Assessments (EIA) that are used to assess local impacts in detail.

Environmental LCA is structurally open to a stepwise **extension to a full sustainability assessment** that includes Life Cycle Costing (LCC) and social LCA. Social LCA covers aspects such as job creation, equal pay for women, etc. This integration is possible because the basis of any environmental LCA is the technical life cycle model of the analysed product, i.e. its complete supply chain, use and end-of-life treatment. In environmental LCA, the environmental information on resource use and emissions is related to each of the process steps of this technical life cycle model. In the same way, cost and social information can be related to these very same process steps. A limited number of such integrated studies have been carried out in research and industry since about 2000. An integrated, authoritative approach for such an integrated life cycle sustainability assessment still needs to be developed.

# 3. ILCD HANDBOOK AND ITS ROLE IN POLICY AND INDUSTRY


*Figure 4: The ILCD Handbook documents launched in March 2010.*[33]

## 3.1 The ILCD Handbook guidance documents

The ILCD Handbook is the core of the ILCD. This Handbook is a series of technical guidance documents that cover all the steps necessary to perform any kind of LCA, including collecting and modelling the data required for such assessments. They provide guidelines for good practice in LCA by industry and government.

The main direct users of the ILCD Handbook documents are LCA practitioners and reviewers. Non-LCA experts in governments and industry can use the ILCD Handbook indirectly as a basis for quality assurance and reliable life cycle-based decision support: to this end they can request 'ILCD compliance' for life cycle-based developments. Annex A provides more details on this with example formulations suggested for different cases, ranging from standardisation mandates to policy documents.

The ILCD Handbook documents are briefly characterised below. They are described in more detail in Annex B. The bibliographical references are given in Chapter 4.

- **ILCD Handbook – General guide for Life Cycle Assessment – Detailed guidance**

  This document provides detailed information for good practice in LCA for ILCD-compliant LCI data development and LCA studies for any kind of system and any kind of life cycle-related question. The guidance document is differentiated for the four main types of questions addressed with LCA; Annex B.1 has more details on this. It defines what type of review is required, identifies the use of nomenclature and sets requirements for the impact assessment methods to be used. This document cross-references the other ILCD Handbook documents for more details on the respective aspects (e.g. review). The 'General guide' addresses practitioners of LCA studies and those who develop LCI data sets as well as the reviewers of these.

[33] The most requested ILCD Handbook document, the 'General guide for Life Cycle Assessment – Detailed guidance', was downloaded over 7 000 times in the four months following its launch.

- **ILCD Handbook – General guide for Life Cycle Assessment – Provisions and Action Steps**

  This document is mainly a summary of the provisions of the 'General guide for Life Cycle Assessment – Detailed guidance', but without explanations, examples, etc. It is a condensed document for more experienced practitioners and reviewers and outlines what is required for ILCD-compliant LCA studies and data.

- **ILCD Handbook – Specific guide for Life Cycle Inventory data sets**

  This document is based on the provisions of the 'General guide', but provides dedicated guidance for more experienced practitioners who develop ILCD-compliant LCI data sets. It covers the conception, development, reporting and review of such data.

- **ILCD Handbook – Recommendations based on existing environmental impact assessment models and factors for Life Cycle Assessment in a European context**

  This document describes specific LCIA models and indicators (methods) to be used by default. This is developed as far as methods of a minimum required reliability and robustness are currently available, and should be updated as new methods appear. Recommendations are given for the impact categories of climate change, ozone depletion, human toxicity, particulate matter/respiratory inorganics, photochemical ozone formation, ionising radiation, acidification, eutrophication, ecotoxicity, land use, material and energy resource depletion and water depletion. All impacts are assessed in the overall framework of three areas of protection: human health, the natural environment and natural resources. As far as possible and with different recommendation levels, methods applicable at a global or at least a European level are recommended. This document is primarily aimed at helping LCA practitioners to help select recommended impact assessment methods. It is also addressed to LCIA developers and serves as a reference for reviewers.

- **ILCD Handbook – Framework and requirements for Life Cycle Impact Assessment models and indicators**

  This document provides the general framework and requirements for systematically developing or checking models that are used to analyse emissions to air, water and soil, and resources used in terms of their contributions to pressures on human health, the natural environment and the availability of natural resources. It describes the LCIA methods used for the calculation of pressure indicators, both in terms of individual impact categories such as climate change or acidification and in terms of overarching areas of protection such as human health, the natural environment and natural resources. It is primarily addressed to the developers and reviewers of LCIA methods.

- **ILCD Handbook – Review schemes for Life Cycle Assessment**

  This document defines the minimum review levels to be met under the ILCD for LCA activities and some key direct applications (e.g. developing LCI data sets, performing LCAs, developing ecolabel and ecodesign criteria), and for specific guides derived from the ILCD Handbook (such as Product Category Rules (PCR) and other product- or sector-specific guides). It also clarifies when stakeholders/interested parties should be involved, describes the main steps for performing reviews and outlines what is required of reviewers and their qualifications. It is complemented by the upcoming document 'ILCD Handbook – Review scope, methods and documentation' (see below). This document is addressed to reviewers of LCAs, LCI data sets and of key direct applications of LCA.

- **ILCD Handbook – Reviewer qualification for Life Cycle Inventory data sets**

  This document defines the minimum qualification requirements of reviewers under the ILCD review schemes for reviewing LCI data sets. This 'qualification' includes the reviewer's independence and the minimum methodological, technical and review process expertise and experience that is required. This document also describes how to evaluate the reviewer's qualification. It is addressed to reviewers of LCI data sets and to ILCD system operators to help identify eligible reviewers.

- **ILCD Handbook – Review scope, methods and documentation** *(under development)*

  This document will define the details of the review tasks to be performed. This includes the level of detail ('scope') that is to be reviewed, which specific methods of review are to be applied (e.g. sample calculations, comparison to other sources, etc.), and recommends a template for documenting the findings of the review. It is addressed to reviewers of LCAs, LCI data sets and of key direct applications of LCA.

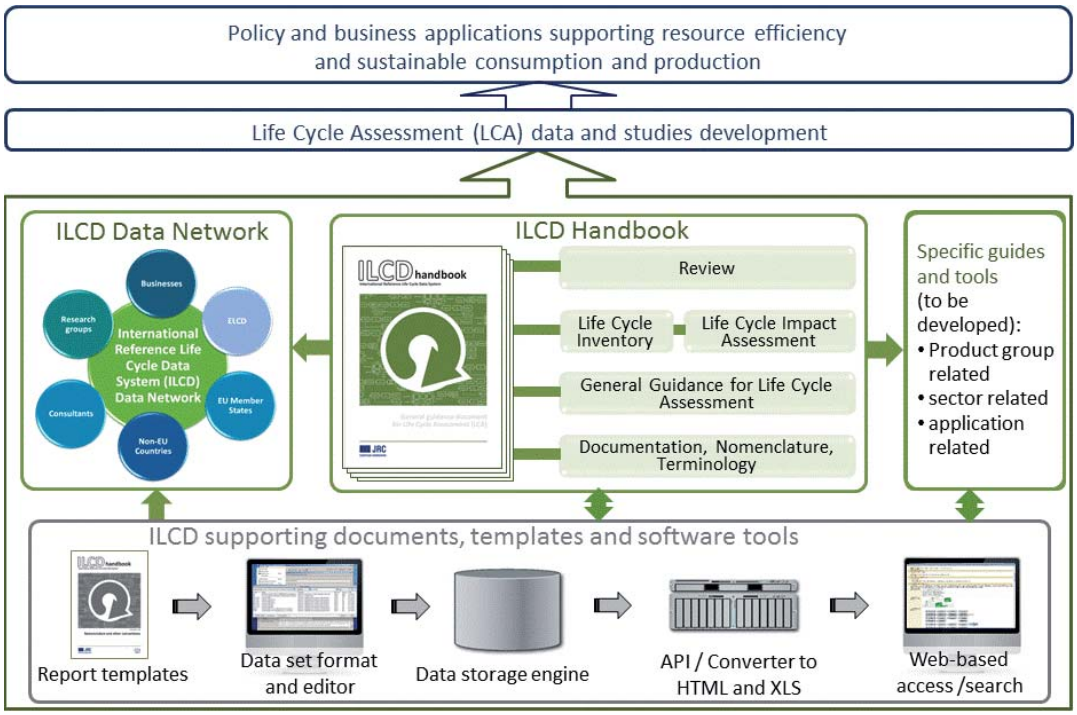


*Figure 5: Schematic overview of the International Reference Life Cycle Data System, including the ILCD Handbook, Data Network and supporting documents, templates and tools.*

- **ILCD Handbook – Nomenclature and other conventions**

  This document details the nomenclature and other provisions for a number of basic data objects used in LCA, such as emission and resource flows, measurement units, etc. It provides nomenclature requirements that must be adhered to when developing data sets for the ILCD Data Network and for calculating and reporting LCA results. It is addressed to LCA practitioners and LCIA method developers, and serves as a reference for reviewers.

- **ILCD Handbook – Terminology**
  *(under development)*

  This document will provide a comprehensive multi-language terminology of technical terms for LCA. It is expected to be available online – initially only in English – as a database or via a content management application. It is addressed to all LCA practitioners, reviewers and LCIA method developers.

The basis for the ILCD Handbook document 'Recommendations based on existing environmental impact assessment models and factors for Life Cycle Assessment in a European context' is the **background document** 'Analysis of existing Environmental Impact Assessment methodologies for use in Life Cycle Assessment'.

The **ILCD Handbook** and the upcoming **ILCD Data Network** make up the International Reference Life Cycle Data System (ILCD), together **with various documents, templates and software tools as well as presentations** that support them, as illustrated in Figure 5. They can all be accessed at http://lct.jrc.ec.europa.eu/assessment/publications.

## 3.2 ILCD-compliant specific guides and software tools

Due to the need to cover a very wide range of products and other systems and the wide range of questions that are analysed using LCA, the ILCD Handbook guidance documents are both comprehensive in coverage and formulated in a very generic manner. The development of **dedicated guidelines for specific questions, product groups and sectors** would be beneficial. Such guidelines are expected to substantially reduce the effort and cost of developing LCI data sets and of carrying out LCA studies, and should further increase their reproducibility and hence acceptance in practice.

Specific guidance documents and related software tools that can be developed by any organisation (e.g. industry associations, national LCA projects), are **recognised by the ILCD Handbook** as long as they are fully compliant with the ILCD Handbook. To ensure compliance, they must be subjected to a review including the involvement of interested parties. Such specific guidance documents can, for example, be PCR, sector-specific guidelines and guidelines for specific applications, such as guidelines on consequential modelling of energy systems, guidelines for developing ecolabel criteria for energy-related products, etc.

The aforementioned software tools are the software implementations of such specific guides that often include life cycle data. Given the recognised status that such specific guidelines can have in the ILCD, it is important that they do not create a market monopoly for related software tools and specific data. This means that specific guidelines must be fully available for free use

and **must not create biases**; the review and the involvement of interested parties should ensure this. The use of derived software tools and specific data cannot be exclusive, i.e. it must be possible to use other software tools that implement the same specific guideline.

## 3.3 What does the ILCD Handbook offer to different target audiences?

The ILCD Handbook is written for LCA practitioners, i.e. experts. For the non-technical audience it serves as a basis for 'good practice' that can be referred to when drawing up life cycle-based policies, service and research contracts, etc. Please see Annex A for dedicated suggestions on how to formulate such references. To summarise:

**Non-technical audience**

- **For public authorities** it provides a reference for ensuring coherence and quality when developing, implementing and monitoring life cycle-related policies, preparing related service contracts and research calls, or issuing standardisation mandates;
- **For industry**, the ILCD Handbook provides a reference that can be used for company policies and for in-house activities and service contracts related to environmental product improvement, developing technology strategies, etc.

**Technical/expert audience**

- **For LCA practitioners and experts** in any kind of organisation, the ILCD Handbook provides comprehensive guidance on all aspects and all questions currently addressed by LCA, and for any kind of products and other systems that are being analysed (e.g. technologies, policy options, companies, events, etc.);
- **For developers of specific guides**, such Product Category Rules (PCRs) and guides for a particular sector from industry associations or authoritative bodies, it provides a reference for many of the common issues to be taken into consideration;
- **For developers of life cycle-based software tools** who implement such specific guides, it provides the basis and defines the requirements to make these tools ILCD-compliant. Based on specific guides as outlined above, more straightforward software tools can be developed that in many cases may no longer require an LCA expert to use them. Technical experts, including product developers or designers of SMEs, waste managers, etc., can directly use such dedicated LCA-based software, obtaining reliable decision support for most day-to-day cases;
- **For developers of specific life cycle-based product criteria** such as those used in labelling, for environmentally conscious design, and for green procurement criteria, the ILCD Handbook can serve as a reference for selecting good-quality LCA studies and data that support the identification of these criteria;
- **For developers of LCI data sets and databases**, it provides the basis for developing quality-assured and consistent ILCD-compliant data sets.

## 3.4 ILCD Handbook – overcoming key obstacles to the wider uptake of LCA

### *3.4.1 Obstacles to the wider uptake of LCA in industry and policy*

Based on the ISO standards, LCA has matured over the past decade. However, despite its potential and the important benefits it can provide, LCA is only now slowly finding its place in industry and policy support. It has not yet reached mainstream use in industry (although carbon-footprint labelling schemes are becoming more established as an application based on life cycle information). The main reasons for this situation, only now being overcome, are:

1. **Reproducibility**: Reproducibility of the results and recommendations of LCAs cannot yet be satisfactorily guaranteed. This is because the relevant ISO standards leave too much room for interpretation by practitioners modelling life cycles of products;
2. **LCI data availability and quality**: The achievable quality of LCAs and, hence, robustness of decision support has been limited by the relatively low availability of high-quality and consistent data;
3. **Uncertainty of impact assessment methods and factors**: LCIA methods often have a high degree of uncertainty and for some important impact areas (e.g. land use, water overuse) there are as yet no robust and fully practice-tested methods;
4. **Quality assurance**: No clear requirements were available on how to select qualified and independent reviewers, how to run the review process, and its exact scope and the review methods to be applied in order to carry out a widely accepted quality assurance of life cycle data and assessments;

5. **Cost and complexity/lack of practicality**: Reliable LCAs are often perceived to be too resource- and time-consuming, requiring dedicated experts, and hence of limited practicality.

### *3.4.2 Achievements of the ILCD developments*

The ILCD addresses the aforementioned obstacles as described below.

The **ILCD Handbook** documents provide a dedicated and complete stepwise solution to help overcome obstacles **1 (reproducibility)** and **4 (quality assurance)**. Figure 6 illustrates the concept of this approach, with each guidance level being increasingly more specific but compliant with the preceding one. The amount of guidance material increases with the comprehensive ILCD Handbook building on the very condensed ISO standards, but decreases for the product/sector-specific guides, yielding both efficient and effective day-to-day manuals. Please note that all development steps include the consultation of other complementary material, such as other guidelines and publications (not shown in the graphic).

Relevant progress has also been made on issue **3 (uncertainty of impact assessment methods and factors)**, for example by identifying and recommending the use of the most advanced, robust and reliable LCIA methods currently available, while pointing out specific needs for improvements.

The ILCD Handbook also contributes to overcoming issue **5 (cost and complexity of LCAs)** by providing the reference document for developing application-specific and product/sector-specific guides (see Figure 6) and simplified software tools. Cost savings are also expected as a result of using a common basis of technologically compatible and methodologically consistent ILCD-compliant data. This substantially eases the combined use of data from different developers. This is expected to help move towards more robust quality-assured studies that limit the need and hence costs for repeated studies of the same systems and questions. While it is difficult to quantify the absolute savings, it is expected that a high percentage of costs related to life cycle-based decision support will be saved by adopting this approach.

The **ILCD Data Network and the supporting documents, software tools and data** will provide the necessary infrastructure and workflow support to tackle issue **2 (LCI data availability and quality)** and complement the quality

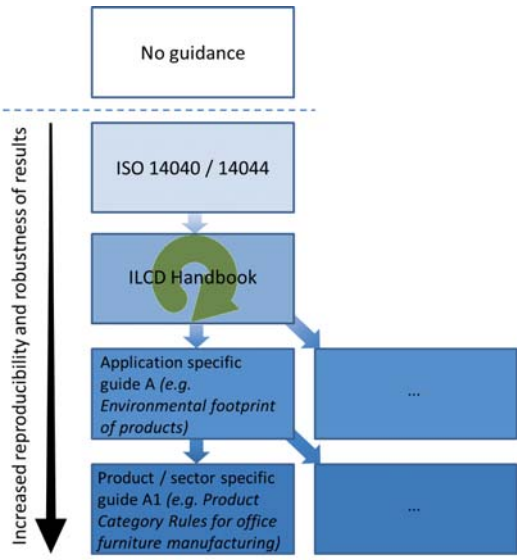


*Figure 6: The concept of increased reproducibility and robustness of LCA using the ILCD Handbook and complementary ILCD-compliant application-specific and product/sector-specific guidelines.*

requirements set in the ILCD Handbook. This helps life cycle data developers in industry, national database projects, in research and consultancies to provide compatible and quality-assured data to users via a data network that is not in competition with existing data sources (see Annex C). The **ELCD**[34], a parallel development to the ILCD Handbook, is already available online. Its European LCI data sets provide a key input to help improve "life cycle data availability and quality". The ELCD is intended to contribute to the ILCD Data Network. The data sets of the ELCD originate from leading EU industry associations and other sources and cover key materials, energy carriers, transport and waste services.

### *3.4.3 Limitations and complementarity to other developments*

**Limitations of the ILCD Handbook**

The limitations of the ILCD Handbook are initially those of (environmental) LCA, which were briefly described in Chapter 2.3.

The overall aim was to make the ILCD Handbook generally applicable, so the result is a very comprehensive guide. Which parts of the Handbook are relevant for the user depends on the specific product/sector and application that the user is interested in. The Handbook is, moreover, formulated in a **generic** manner, so the text must be interpreted to understand its application to the specific product or activity/sector that is being analysed in a study. The development of specific ILCD-compliant guides and software tools for different applications, sectors and products is therefore expected to

[34] http://lca.jrc.ec.europa.eu/assessment/data

improve the efficiency of daily LCA work in line with the ILCD Handbook to further improve reproducibility; see also Chapter 3.2.

Particularly for the use of LCA in **strategic and policy decision support (policy impact assessment)**, the related guidance in the ILCD Handbook (Situation B in the 'General guide') would benefit from further input. While micro-level/product LCA is fairly well developed and comprehensively covered in LCA theory, the methodology of macro-level LCA applications needs to be developed further.

The ILCD Handbook provides limited detail on **supporting methods such as scenario formation and uncertainty calculation**. However, this is well established in complementary literature and guidelines.

Finally, in existing LCA guidance documents, there is a notable lack of guidance on **raw data collection and documentation** as the input for developing unit process data sets – the basic building blocks of life cycle models. The related guidance in the 'General guide' should be extended and a documentation format should be developed.

**Complementarity of the ILCD Handbook to other LCA-related developments**

On an international level, several **other LCA-related method developments are being carried out by a range of public and private actors**. These are generally moving towards approaches that are coherent with those of the ILCD Handbook, which is a recognised key input to these initiatives. These international activities include the Greenhouse Gas Protocol initiative (led by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD)[35]), the US-based multi-stakeholder Sustainability Consortium[36], the ISO work towards a carbon footprint of products standard (ISO 14067)[37], and the joint UNEP/SETAC Life Cycle Initiative as another multi-stakeholder project[38]. While the scope of most of these developments is covered by the ILCD Handbook, the recent development of a document with guidance principles for LCA databases, coordinated by UNEP and SETAC, has some elements which are complementary to the ILCD Handbook.

Among the **EU Member States**, the revision of the British 'PAS 2050: Specification for the assessment of the life cycle greenhouse gas emissions of goods and services' and the pilot phase implementation of the French 'BP X 30-323: General principles for an environmental communication on mass market products' under the Grenelle 2 law refer to and make use of the ILCD Handbook.

The ILCD Handbook and the JRC's active involvement in the respective **Advisory Groups, technical committees and the consultations** of these and other activities have contributed to these ongoing efforts to develop more coherent approaches. However, differences are expected to result in some incompatibilities of the data and studies developed, and will require further efforts of international harmonisation.

**Outlook for a wider sustainability assessment**

The ILCD Handbook deals with **'classical', i.e. environmental, LCA**. Environmental LCA and hence the ILCD Handbook have several limitations, as described in Chapter 2.3. The ILCD Handbook is therefore limited insofar as it does not cover, for example, health-related impacts of direct product application and intake or of accidents. **Human health risk assessment** approaches that cover the direct effects of products on humans can be integrated coherently with LCA, particularly by quantifying the average potential human health impact in relation to the amount of product applied. Similarly, impacts on humans and the environment as a result of accidents can also be integrated via **Life Cycle Accident Assessment** methods.

Environmental LCA does not address **social and economic elements** of the product life cycle. For an integrated sustainability assessment, the ILCD Handbook needs to be complemented by other instruments that capture social and economic aspects of the analysed systems. **Social LCA** (that includes Life Cycle Working Environment and some elements of Life Cycle Accident Assessment) and LCC are instruments that are closely related conceptually and can be fully coherent with the (environmental) LCA provisions of the ILCD Handbook. They can be integrated with the ILCD guidance on environmental LCA to develop guidance on complete life cycle-based sustainability assessment.

The coherent integration of complementary information and methods, combining the ILCD Handbook with authoritative guides from other domains, could lead to a comprehensive, systematic approach for performing efficient and fully **integrated environmental, economic and social life cycle-based sustainability assessments**.

[35] http://www.ghgprotocol.org/
[36] http://www.sustainabilityconsortium.org
[37] http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=59521
[38] http://lcinitiative.unep.fr/

# 4. ILCD DEVELOPMENT AND ACKNOWLEDGEMENTS

## Development approach

Building on the relevant ISO 14040 and 14044 standards and a wide range of existing guidance documents on LCA data and studies from national projects, industry associations, research groups and consultants, the ILCD Handbook represents a comprehensive scientific methodological guidance. Its use in policy and industry is the next step. It can be used directly, or form the basis for developing further application-specific and product/sector-specific guides and decision support tools. The different actors who would like to work with the ILCD can build on its coherent scientific basis and tailor it to their needs.

Figure 7 illustrates the **approach taken in developing the ILCD Handbook** as guidelines that reflect available good practice in LCA. The complete list of all sources is provided in Annex D. The individual sources are listed as an Annex to the respective guidance documents.

The ILCD Handbook was conceived as a comprehensive set of guidance documents for LCA practitioners, to cover all types of systems analysed with a life cycle approach and for all kinds of questions, with a focus on environmental impacts. Based on initial draft guidance documents and prepared with the help of different contractors, two rounds of consultations were held.

## Invited stakeholder consultations

Early drafts of the documents were distributed in 2008 to more than 70 organisations and groups. These included:

- the 27 EU Member States via the Integrated Product Policy (PPP) Regular Meeting,
- various European Commission services,
- six national Life Cycle Database initiatives outside the European Union,
- the UNEP,
- 16 EU-level industry associations which were members of the European Business Advisory Group,
- 15 LCA software and database developers which were members of the LCA software and database developers Advisory Group,
- seven LCIA method developers which were members of the LCIA method developers Advisory Group.

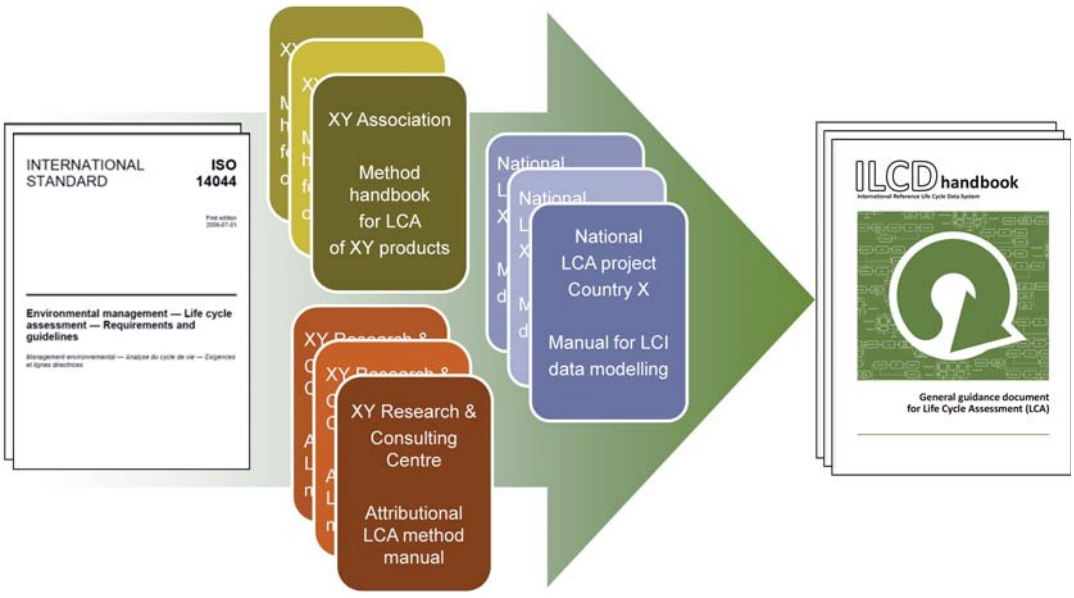


*Figure 7: Guidance for best practice in LCA: the ILCD Handbook documents, derived from a range of manuals, based on and in line with ISO 14040 and 14044.*

*Figure 8: Four-day public consultation workshop, 29 June to 2 July 2009, Brussels.*

This consultation process was supported by dedicated technical meetings with the Advisory Groups and by presentations to and discussions with the wider scientific community in the context of international conferences.

## Public consultation

Public consultations were carried out on the advanced draft guidance documents of the ILCD Handbook, each typically lasting eight weeks. Some selected supporting documents and software solutions were also publicly consulted (particularly the data set format and the review report template). For the main set of the ILCD Handbook documents, the public consultation included a four-day public consultation workshop, which took place from 29 June to 2 July 2009 in Brussels (see photos in Figure 8).

The full list of invited consulted parties and of contributors to the individual public consultations is provided as an Annex to each of the ILCD Handbook documents.

## Finalisation and public launch

The first edition of the main set of ILCD Handbook guidance documents was publicly launched in Brussels on 12 March 2010 by the Commissioner for the Environment Janez Potočnik. Speakers at the launch event included JRC-IES Director Leendert Hordijk, JRC Director of Programmes and Stakeholder Relations David Wilkinson, DG Environment's Director of Sustainable Resources Management, Industry & Air Soledad Blanco, and Clare Broadbent as a representative of worldsteel, the international trade body of the global iron and steel industry (see photo in Figure 9).

Three more documents ('Nomenclature and other conventions', 'ILCD Data Network – Compliance rules and entry-level requirements' and 'Recommendations based on existing environmental impact assessment models and factors for Life Cycle Assessment in a European context') were finalised and published at the end of 2010, early 2011 and the end of 2011 respectively. Two further documents ('Review scope, methods and documentation' and 'Terminology') are expected later in 2012.

Furthermore, dedicated review panels have been contracted and they have reviewed the first editions of the documents that have already been published – to provide input for a potential future revision.

## Drafting and financing, acknowledgements

The ILCD Handbook documents were initially drafted by different contractors (see the acknowledgements in the respective documents) via support contracts financed by the European Commission's Joint Research Centre (JRC) and Institute for Environment and Sustainability (IES). The guidance documents were finalised by JRC-IES staff, who integrated the feedback from the consultations.

The work on the ILCD is funded by the European Commission, partially supported through Commission-internal Administrative Arrangements (No 070402/2005/414023/G4, 070402/2006/443456/G4, 070307/2007/474521/G4 and 070307/2008/513489/G4) between DG Environment and the JRC.

*Figure 9: Launch of the ILCD Handbook, 12 March 2010, Brussels.*

The ILCD data set format, ILCD data set editor and other ILCD Data Network IT tools have been developed under the Collaboration Agreement No 382956 SOC between the European Union represented by the European Commission's JRC-IES, the Research Centre Karlsruhe-Institute for Applied Computer Science (FZK-IAI – now under the Karlsruhe Institute of Technology as KIT-IAI) in Germany, and the Brazilian Institute of Information on Science and Technology (IBICT) under the Brazilian Ministry of Science and Technology.

The valuable contributions provided by the participants in invited and public consultations on the various documents – literally hundreds of pages of technical comments – are gratefully acknowledged. They have made a substantial contribution to ensuring comprehensiveness and to balancing scientific precision and practicality in achieving the required guidance on good practice in LCA in a policy and industry context.

**Disclaimer:** Involvement in the development or consultation process does not imply agreement

# 5. BIBLIOGRAPHICAL REFERENCES ILCD HANDBOOK

Access point: all ILCD Handbook documents, the ILCD Data Network, the ELCD Database and supporting software tools, templates, data, etc. are accessible via the life cycle website hosted by the European Commission´s JRC: http://lct.jrc.ec.europa.eu/assessment/publications.

The entirety of the ILCD Handbook can be referenced as follows:

**European Commission – Joint Research Centre – Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook. Series of guidance documents for good practice in Life Cycle Assessment. First edition 2010-2011. Luxembourg. Publications Office of the European Union; 2010 and 2011.**

The following references refer to the individual components of the ILCD Handbook. The approximately 300 documents and scientific papers that were explicitly considered when developing the ILCD Handbook are referenced in Annex D.

**Individual components of the ILCD Handbook:**


1. European Commission – Joint Research Centre – Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook – **General guide for Life Cycle Assessment – Detailed guidance**. First edition March 2010. EUR 24708 EN. Luxembourg. Publications Office of the European Union; 2010.

2. European Commission – Joint Research Centre – Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook – **General guide for Life Cycle Assessment – Provisions and Action Steps**. First edition March 2010. EUR 24378 EN. Luxembourg. Publications Office of the European Union; 2010.

3. European Commission – Joint Research Centre – Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook – **Specific guide for Life Cycle Inventory data sets**. First edition March 2010. EUR 24709 EN. Luxembourg. Publications Office of the European Union; 2010.

4. European Commission – Joint Research Centre – Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook – **Framework and requirements for Life Cycle Impact Assessment models and indicators**. First edition March 2010. EUR 24586 EN. Luxembourg. Publications Office of the European Union; 2010.

5. European Commission-Joint Research Centre – Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook- **Recommendations for Life Cycle Impact Assessment in the European context**. First edition November 2011. EUR 24571 EN. Luxemburg. Publications Office of the European Union; 2011.

6. European Commission – Joint Research Centre – Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook – **Review schemes for Life Cycle Assessment**. First edition March 2010. EUR 24710 EN. Luxembourg. Publications Office of the European Union; 2010.

7. European Commission – Joint Research Centre – Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook – **Reviewer qualification for Life Cycle Inventory data sets**. First edition March 2010. EUR 24379 EN. Luxembourg. Publications Office of the European Union; 2010.

8. European Commission – Joint Research Centre – Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook – **Review scope, methods and documentation**. Document under development.

9. European Commission – Joint Research Centre – Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook – **Nomenclature and other conventions**. First edition 2010. EUR 24384 EN. Luxembourg. Publications Office of the European Union; 2010.

10. European Commission – Joint Research Centre – Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook – **Terminology**. Document under development.

**Key supporting documents**

11. European Commission – Joint Research Centre – Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Data Network – **Compliance rules and entry-level requirements**. Version 1, 2010. EUR 24380 EN. Luxembourg. Publications Office of the European Union; 2010.

12. European Commission – Joint Research Centre – Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook **background document – Analysis of existing Environmental Impact Assessment methodologies for use in Life Cycle Assessment**. First edition March 2010. Luxembourg. Publications Office of the European Union; 2010.

# ANNEX A: HOW TO USE THE ILCD IN POLICY, STANDARDISATION, AND RESEARCH AND DEVELOPMENT

## A.1. Overview

The ILCD Handbook has been developed to guide good practice in LCA. So, for ensuring quality and consistency, the ILCD Handbook can be referred to in life cycle-related policies, in standardisation, as well as in LCA-related scientific calls for tender. A request can be made for 'ILCD compliance'.

Any LCA work can be developed in compliance with the ILCD and hence ILCD compliance can be requested for any kind of document that requires, for example, LCI data sets to be developed, an LCA study to be performed, sector-specific LCA guidelines or tools to be developed, or similar. Among the ILCD Handbook documents, the 'General guide for Life Cycle Assessment – Detailed guidance' explicitly specifies what ILCD compliance means and what is required to claim it[39].

The 'ILCD Handbook – General guide for Life Cycle Assessment' differentiates four types of LCA applications, called Situations. The Handbook defines which specific LCA application belongs to which Situation and what this implies, for example for the methodology to be used when performing related LCAs. The relevant part of the related 'Provisions 5.2: Classifying the decision context' are reproduced in Annex B.1 of this report. Generally, it can be left to the LCA experts to identify and justify the correct application type and applicable Situation for any given LCA activity, as this step is in fact part of the guidance. Only in the case of specifically compiling/developing LCI data sets for publication, e.g. via the ILCD Data Network, must the type of LCA application for which the data sets are to be developed be specifically mentioned in contracts.

The bibliographical reference to the ILCD Handbook as a whole is provided in Chapter 4; it should be used to ensure proper identification of what exactly compliance with the ILCD Handbook – or in short ILCD compliance – refers to.

In summary and on a general level, the following can be requested:

- *"The deliverable(s) shall be ILCD-compliant."*

This request can be made for all kinds of life cycle-based developments, such as LCI data sets, assessments, decision support, ecolabel and ecodesign criteria, sector- and product-specific guides, etc. For LCI data sets, it can be further requested that these shall meet at least one of the following quality levels:

- *"data estimate"*, *"basic quality"* or *"high quality"*

These levels are defined in the 'ILCD Handbook – General guide for Life Cycle Assessment – Detailed guidance', Chapter 12.3. Note that the criteria for 'high quality' are rather demanding and typically can only be met with direct involvement of, for example, the producing/operating companies and with access to the quantitative data on emissions, consumables, intermediates, main services, etc. of the sites/processes involved.

[39] The 'General guide' (first edition) says in 'Provisions: 2 How to use this document', provision I: "*An LCI or LCA study or data set and direct LCA applications can claim compliance with the ILCD Handbook. For this they shall have been developed in line with the provisions of this document as specified in the "Provisions", including the provisions made in referenced documents and complementing information that may be given in the main part of the document, e.g. in supporting tables or in the "terms and concepts" boxes. Also specific LCI/LCA guidance documents (e.g. product group, sector or process type-specific guides) and PCR can claim ILCD compliance. This applies if their provisions are compliant with the broader provisions of the ILCD Handbook and if they have undergone an ILCD-compliant review as specified in the separate document "Review schemes for Life Cycle Assessment"*."

It is expected to take up to three years for industry associations to update and modify their data in order to be able to provide broadly consistent and quality-assured ILCD-compliant data via the ILCD Data Network. It will therefore be necessary to limit the requirements for attaining full ILCD compliance in the development of LCA data and in carrying out studies during these first years[40]. The main factor that could delay the carrying out of fully ILCD-compliant studies is the availability of ILCD-compliant LCI data sets of widely used goods and services that form part of the life cycles of most other goods and services. The 'entry-level' requirements of the ILCD Data Network have been defined in order to facilitate the gradual accumulation of such data, while providing a way to carry out ILCD-compliant studies. The following, less strict requirement should only be used for LCI data sets where full ILCD compliance is considered to be unachievable[41].

- *"The life cycle inventory data sets to be used/developed shall meet at least the 'ILCD Data Network entry-level' requirements."*

Such data sets already go beyond ISO 14040 and 14044: they provide better quality assurance, documentation and IT compatibility across different sources than the ISO standards. If this requirement is put in place, the specific supporting document 'ILCD Data Network – Compliance rules and entry-level requirements', which defines this entry-level, is to be referenced in addition to the reference to the ILCD Handbook. Note: This entry-level requirement is also the suggested minimum requirement for all LCI data sets to be eligible for distribution as part of the ILCD Data Network.

The following sub-chapters provide more details and explanations and propose more specific formulations for using and referencing the ILCD Handbook in policy and market contexts.

[40] Note that this restriction does not apply to the development of application-specific and product/sector-specific guides for LCA, i.e. for these, ILCD compliance can be requested directly.

[41] Note that this entry-level does not require full methodological consistency of the data; this would require requesting 'methodological ILCD compliance'. However, the data sets would already be in line with the relevant ISO 14040 and 14044, i.e. they would have achieved a minimum quality level as an interim step towards full ILCD compliance.

## A.2. Public policies

Technical annexes of directives and regulations are examples of key technical requirements being set for the implementation of policies.

ILCD Handbook compliance helps to ensure that life cycle-based work performed in the context of a policy is robust, consistent and independently quality assured.

The following wording can be used in, for example, a policy framing the identification of more and less environmentally friendly products where LCAs are to be directly conducted when implementing the policy:

- *"This is to be demonstrated by ILCD-compliant Life Cycle Assessments."*

This formulation can also be used to address individual producers of products to either demonstrate their environmental preference or to justify exemptions of their products. It can also be used to steer the development of, for example, product group-specific criteria, tools or guidelines that support the implementation of such a policy.

However, if such a policy were to come into force in the near future, e.g. before the end of 2014, it is recommended that the wording be mitigated by including a text such as:

- *"In case fully ILCD-compliant studies cannot be developed, the studies shall follow as many of the ILCD compliance requirements as reasonably possible. They shall moreover explicitly consider any non-compliance in the interpretation of the results and when drawing conclusions and giving recommendations. In any case, these studies have to conform to ISO 14040 and 14044 and be independently externally reviewed. Non-ILCD-compliant elements are to be documented and the effect be considered in the interpretation."*

Wherever the use of LCI data sets need to be referenced:

- *"Life cycle inventory data used for (...) shall be ILCD-compliant."*

It can be added that preference shall be given to any available data from the relevant industry associations (or companies, for more specific data sets). Please note that ILCD compliance has robust requirements for qualified and independent review. Therefore, such a preference for industry data is not expected to lead to a distortion of the results:

- *"If available, ILCD-compliant data sets provided by, or formally approved by, the industry representing the product shall be preferred over other data sources."*

As for LCAs, an adjusted formulation can be used for data sets and related policies that enter into force in the near future, e.g. before the end of 2014 (see above).

Wherever the calculation of environmental impacts is to be made on a specific impact topic (e.g. climate change for carbon footprints) or the overall environmental impact is being explicitly focused on, the use of the ILCD-recommended LCIA methods can be requested[42]:

- *"The impacts related to* (impact name) … /*The overall environmental impacts shall be calculated using the recommended LCIA methods of the ILCD Handbook."*

Please note: When requesting ILCD compliance for LCA studies, the above-mentioned criterion is already implicitly included.

### A.3. Policy support studies/impact assessments

Preparative studies that inform policy developers about the environmental implications of different policy options (policy impact assessments) need to be robust and reliable. Among the guidance documents of the ILCD Handbook, provisions are provided that explicitly refer to strategic/policy studies. The following formulations can be put into related service contracts:

- *"The Life Cycle Assessments shall use ILCD-compliant studies and data wherever available. These can be complemented by other studies – independently externally reviewed studies as a minimum – and data that conform to ISO 14040 and 14044 standards. Non-ILCD-compliant elements are to be documented and the effect considered in the interpretation."*

The ILCD provisions include the review and interpretation of results and hence can be considered as strengthening the robustness and defendability of the outcome of such policy impact assessments. At the same time, the ILCD Handbook focuses on the LCA domain and is open to incorporating other environmental, social and cost criteria into the evaluation. Hence it offers a dedicated building block or starting point for a broader policy impact assessment. See also Chapter 3.4.3, subsection 'Outlook for a wider sustainability assessment'.

### A.4. Standards, ecolabel and ecodesign criteria, specific guides and related software tools, and LCI data

#### *Full ILCD compliance*

Standardisation mandates for specific products or technologies, as well as LCA applications such as Environmental Product Declarations (EPDs) or ecolabelling, can refer to the ILCD Handbook as a reference, ensuring broader coherence and quality.

Similarly, product/sector-specific guides can draw on the ILCD Handbook and claim ILCD compliance. They can even have a formal role within the ILCD, as detailed in Chapter 3.2.

When developing a standard, ecolabel or ecodesign criteria, a specific guidance document and/or software tool or LCI data sets, or commissioning the development of such, the following requirement can be set:

- "*The* (standard/guidance document/guidance document and implementing software tool/LCI data sets) *shall be ILCD-compliant.*"

Please note that, for specific guides and tools, this involves – besides methodological and other requirements – a review of the guidelines or tool. Interested parties must be invited to contribute from the onset of developing the guidelines. It is recommended that related tasks and financial resources be included in the plans for the development of the guidelines.

Particularly for the development of LCI data sets (e.g. as part of a national LCA database), the LCA application to be supported and hence the applicable ILCD Situation needs to be identified upfront. It is recommended that unit process data sets that support all four Situations A, B, C1 and C2 be requested. If this is not possible due to confidential industrial or proprietary data, or in order to make the data more easy to use, Situation A, aggregated LCI results data sets should be requested: Situation A (i.e. product/company level LCAs) covers the most widely used LCA applications and is methodologically identical to Situation C1 (i.e. for monitoring); for details see Chapter 7.1. Situation B data sets (i.e. policy/society-level LCAs) need to be tailored for the specific study, which is why Situation B LCI results data sets are less meaningful for a generic national LCA database.

[42] Please note that these recommended LCIA methods currently refer to emissions occurring in Europe, while generically they can by default be used globally, unless significantly more accurate, dedicated factors become available.

If the development relates to developing a software tool including life cycle data, the following additional reference can be made specifically for the data:

- *"Life cycle inventory data sets included are to be ILCD-compliant."*

Note that it is strongly advised that ILCD compliance also be requested for the software tool in general, as this relates to the implemented life cycle modelling method and also implies certain review requirements.

To benefit from increasing data availability and newer data, it should be requested that the tool include an import interface for ILCD formatted data sets such as those available via the upcoming ILCD Data Network.

### *Partial ILCD compliance*

Even if a new standard or a specific guidance document or tool is not fully ILCD-compliant, it can draw on the ILCD Handbook components to improve reproducibility, quality assurance and other aspects. It is, however, important to stress that this approach does not ensure the achievement of the overall consistency, quality, comparability and compatibility to other ILCD-compliant LCA developments.

Requests can be made in specific guides or tools for the use of ILCD-compliant LCI data sets:

- *"Life cycle data used for* (...) *shall be ILCD-compliant."*

Requests can also be made that the data or activities be in line with any of the compliance components of the ILCD Handbook, particularly:

- '*Method compliance*' for all aspects of LCI, LCIA and other method aspects used for LCA studies;
- '*Review compliance*' for minimum review requirements;
- '*Documentation compliance*' for appropriate documentation of LCA studies and/or LCI data sets;
- '*Nomenclature compliance*' when working with the same basic data objects such as emissions and resources.

These ILCD compliance components are detailed in Chapter 12.4 of the 'ILCD Handbook – General guide for Life Cycle Assessment – Detailed guidance'.

Note: A separate reference to ILCD 'quality compliance' is not useful, as this would necessarily integrate the other compliance components. However, three distinct overall data quality levels are defined in Chapter 12.3 of the 'ILCD Handbook – General guide for Life Cycle Assessment – Detailed guidance'.

## A.5. Scientific calls for tender

### *Preceding remarks*

Research needs to be flexible. At the same time, public money spent on research projects should contribute to wider benefits after the project ends and – particularly for projects working with LCA – help to broaden the publicly available life cycle data basis.

This is especially the case for studies where LCA is used as an instrument to help steer research into technology or product development. Such cases usually involve collecting original life cycle data for the product or technology being analysed (as well as for existing, alternative solutions). Such data sets are of great interest to other LCA practitioners in research and often to industry and experts working in the policy context. Where appropriate, requests can be made in research calls for tender to make the developed data sets available in an easily accessible, well-documented and properly reviewed form, via the ILCD Data Network. At the same time, the LCA-based decision support process carried out during the project should effectively steer the projects towards the environmentally preferable options.

Having said that, data from research projects may not always be able to meet the requirements of the ILCD Handbook. This is the case if the study is mainly of an LCA methodological nature or if it is clear before the project starts – mainly due to a foreseeable lack of access to original information – that a minimum quality level cannot be achieved. Such boundary conditions may limit the possibility of achieving full ILCD compliance.

### *Referencing the ILCD for LCI data sets in R&D project calls*

A suitable reference for research projects that analyse existing or future technologies or products and that generate related life cycle data could be:

- *"Life Cycle Inventory data sets that are developed during the project shall be made publicly available as ILCD-compliant data sets."*

If possible, this should be further detailed as follows:

- *"The data sets shall be made available to the study commissioner for publication* (optional addition: *free of charge for any user and use, and) via the ILCD Data Network. While single operation unit process data sets shall be preferred, in case of well-founded confidentiality concerns, e.g. of industry or other patent/know-how holders of proprietary information, black-box unit processes or aggregated LCI results can be provided instead."*

The effort/cost of publishing the resulting data sets can also be integrated into a project call, i.e. making the data publication part of the project funding, by adding for example:

- *"Funds for installing, registering, and operating an ILCD Data Network node and giving access to the LCI data sets via the data network shall be covered by the funds of this call."*

Note that the required software for such ILCD Data Network nodes will be made available free of charge via the European Commission´s JRC. This software runs on standard web servers.

### *Referencing the ILCD Handbook for decision support in R&D*

To ensure the R&D effort is environmentally steered towards the most advantageous solution, the following can be added regarding using LCA as a decision support tool in R&D projects:

- *"ILCD-compliant Life Cycle Assessment shall be used for environmental decision support in the (technology/product/...) development of the project."*

This can be used for all R&D projects that relate to the development of new products, technologies, raw materials, etc., whether on a micro-scale (specific product) or macro-scale (e.g. a technology family, such as biorefineries).

Please note that life cycle-based economic and social decision support can be combined with this environmental decision support in a modular way.

# ANNEX B: THE ILCD HANDBOOK DOCUMENTS AND THEIR INTERRELATIONSHIP

This annex provides a brief characterisation of the ILCD Handbook documents and how they are interrelated for readers who do not have in-depth knowledge of the subject matter. Technical details are available in the respective guidance documents.

## B.1. ILCD Handbook – General guide for Life Cycle Assessment – Detailed guidance

### *Purpose, scope, and role within the ILCD Handbook*

This guidance document provides detailed provisions and explanations as well as illustrations for planning, developing, and reporting both life cycle emission and resource consumption inventory data sets and LCA studies.

In daily practice, this document provides **comprehensive guidelines and serves as a reference document. It also introduces the main principles and concepts of LCA**. It is not intended, however, to be an introduction or training manual for beginners.

The exact provisions are given at the end of the chapters – together they **define 'ILCD compliance'**. These provisions are also available as separate 'cookbook' style guidelines for daily reference for the more experienced practitioners and reviewers (i.e. the 'ILCD Handbook – General guide for Life Cycle Assessment – Provisions and Action Steps' – see Annex B.2).

This 'General guide' is complemented by the other ILCD Handbook documents; for details see the following subchapters. It is also complemented by supporting documents, templates and software tools, including an LCA study report template and an LCI data set documentation format. These are available separately (see http://lct.jrc.ec.europa.eu/assessment/publications).

### *Summary/approach of this document*

The approach of the 'General guide' is to **further detail the ISO 14040 and 14044 standards and to differentiate them by the three main types of questions** that are commonly addressed by LCA studies. The following list identifies which of these Situations relates to which main type of LCA application:

- **'Micro-level decision support' (Situation A)**: Life cycle-based decision support on the micro-level, i.e. typically for questions related to specific products, processes and sites or companies. Examples are ecodesign, EPDs, environmental and carbon footprint, etc. As opposed to Situation B, these 'micro-level decisions' are assumed to have limited or no market consequences outside the decision context, i.e. they are assumed not to change available production capacity in the economy.
- **'Meso/macro-level decision support' (Situation B)**: Life cycle-based decision support at a strategic level, such as the national or even global level. Examples are studies on raw material strategies, wider technology scenarios, and analysing the environmental implications of policy options. 'Meso/macro-level decisions' are assumed to have market consequences outside the decision context, i.e. they are assumed to change available production capacity in the economy. These decisions are based on both baseline and future-orientated scenario analyses, where consequences of system-level changes can be assessed.
- **'Accounting' (Situation C)**: Purely descriptive documentation of the analysed system's life cycle (e.g. that of a product, company, sector or country), without considering any potential additional consequences on other parts of

the economy. Within 'Accounting', two sub-types are differentiated: one that accounts for existing benefits outside the analysed product system due to recycling, recovery and other co-products (Situation **C1**), and one that does not (Situation **C2**).

Note that methodologically, Situation C1 requires the same life cycle modelling as Situation A.

The 'General guide' document focuses on methodological issues that yield relevant differences in the LCA results. This includes issues that are not at all or only very briefly and implicitly addressed in the ISO standards, but that need to be addressed when carrying out LCA work in practice.

The following list maps the different kinds of LCA deliverables and how they are applied to the aforementioned main application types (Situations):

### *LCA activities and their applications under Situation A – 'Micro-level decision support'*

- Identification of Key Environmental Performance Indicators (KEPI) of a product group for ecodesign/simplified LCA;
- Weak point analysis of a specific product;
- Detailed ecodesign/design for recycling;
- Perform simplified KEPI-type LCA/ecodesign study;
- Comparison of specific goods or services;
- Benchmarking of specific products against the product group's average;
- GPP;
- Development of life cycle-based Type I eco-label criteria;
- Development of PCR or a similar specific guide for a product group;
- Development of a life cycle-based Type III environmental declaration (e.g. EPD) for a specific good or service,
- Development of the 'environmental footprint', 'carbon footprint', 'primary energy consumption' or similar indicator for a specific product,
- Greening the supply chain;
- Providing quantitative life cycle data as an annex to an Environmental Technology Verification (ETV) for comparative use;
- Clean Development Mechanism (CDM) and Joint Implementation (JI);
- Development of specific, average or generic unit process or LCI results data sets for use in Situation A.

### *LCA activities and their applications under Situation B – 'Meso/macro-level decision support'*

- Policy development and impact assessment: Forecasting and analysis of the environmental impact of pervasive technologies, raw material strategies and related policy developments;
- Policy information: Identifying product groups with the largest environmental improvement potential;
- Development of specific, average or generic unit process or LCI results data sets for use in Situation B[43].

### *LCA activities and their applications under Situation C1 – 'Accounting with interactions'*

- Monitoring environmental impacts of a nation, industry sector, product group or product;
- Policy information: Basket-of-products (or product groups) type studies;
- Policy information: Identifying product groups with the largest environmental impact;
- Corporate or site environmental reporting, including indirect effects under Environmental Management Systems (EMS);
- Certified supply type studies or parts of the analysed system with fixed guarantees along the supply chain;
- Development of specific, average or generic unit process or LCI results data sets for use in Situation C1.

[43] In the context of LCI data development, note that Situation B data sets need to be developed for the specific study. LCI results data sets are therefore a less meaningful development for generic use, e.g. in a national LCA database.

***LCA activities and their applications under Situation C2 – 'Accounting without interactions'***

- Accounting studies that according to their goal definition do not include any interaction with other systems;
- Development of specific, average or generic unit process or LCI results data sets for use in Situation C2.

### B.2. ILCD Handbook – General guide for Life Cycle Assessment – Provisions and Action Steps

This document provides a summary of the provisions and action steps for planning, developing and reporting both life cycle emission and resource consumption inventory (LCI, Eco-profile) data sets and LCA studies. Detailed explanations, illustrations and an overview of the main terms and concepts are provided in its sister document 'ILCD Handbook – General guide for Life Cycle Assessment – Detailed guidance' (see Annex B.1), of which this document is essentially an extract.

Within the set of ILCD Handbook documents, this document is a **'cookbook' style reference document for daily use**. Due to its **very condensed and generic** form, it is designed for the experienced LCA practitioner and reviewer only.

### B.3. ILCD Handbook – Specific guide for Life Cycle Inventory data sets

The 'Specific guide for Life Cycle Inventory data sets' (LCI data sets) builds on its parent document 'General guide for Life Cycle Assessment'. It combines the relevant provisions of the general guide to produce more focused and **very condensed and generic guidelines for inventory data set development**.

This guidance document covers both the development of unit process data sets and aggregated LCI result data sets (also called Eco-profiles). The target audience are experienced developers of LCI data sets and databases

### B.4. ILCD Handbook – Recommendations based on existing environmental impact assessment models and factors for Life Cycle Assessment in a European context

This guidance document presents the **ILCD-recommended LCIA methods for Europe**, for modelling the most common impact categories. These methods translate emissions and resources consumed via characterisation factors into impacts on the natural environment, human health and the availability of natural resources. The target audience of this document is the LCA practitioner. By identifying research needs for better LCIA methods, it also informs scientific officers that manage related research budgets.

The recommendations are based on existing LCIA models and characterisation methods, supplemented by a selection of other environmental impact models.

A range of LCIA methods have been developed through research activities and some efforts were already made towards harmonisation prior to the development of the ILCD Handbook. Starting from a first pre-selection of existing methods (see 'ILCD Handbook background document – Analysis of existing Environmental Impact Assessment methodologies for use in Life Cycle Assessment', not described in this JRC reference report) and applying the evaluation criteria (see Annex B.5), this guidance document identifies and describes the recommended methods to be used for LCA in a European context. This recommendation is made for each impact category at midpoint level (i.e. impact

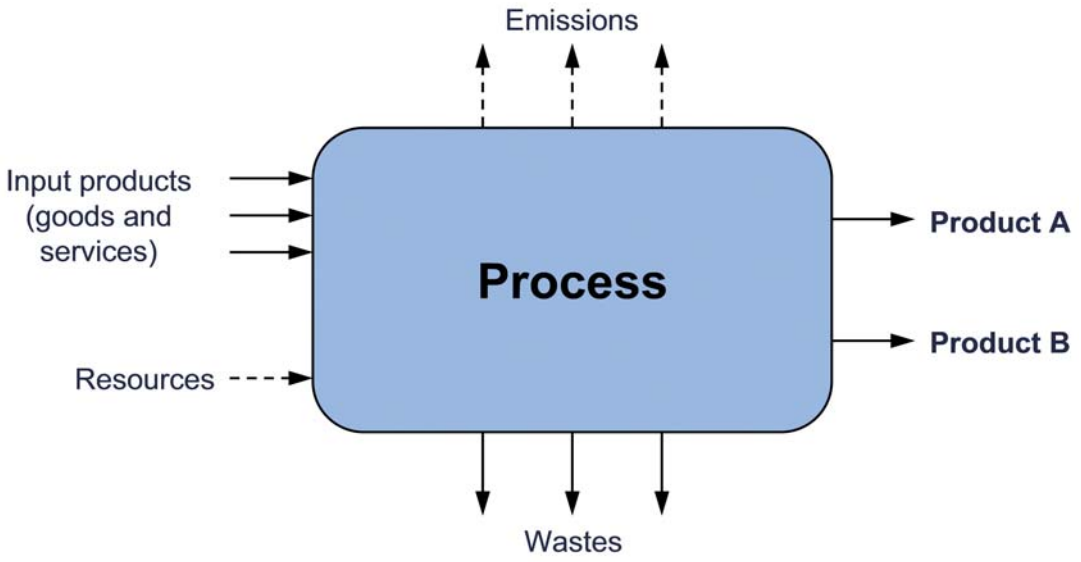


*Figure 10: Unit process, single operation data set that forms the basis of any LCA study.*

categories such as climate change, acidification, etc.) and – as far as advanced methods were available – at end-point level (e.g. impacts on human health due to carcinogenic emissions, loss of biodiversity due to eutrophication, etc.).

Recommendations are given for the **impact categories climate change, ozone depletion, human toxicity, particulate matter/respiratory inorganics, photochemical ozone formation, ionising radiation, acidification, eutrophication, aquatic and terrestrial ecotoxicity, land use, material and energy resource depletion, and water depletion**. All impacts are assessed in the overall framework of the three **areas of protection: human health, natural environment and natural resources**.

**Research needs are identified** for each impact category and prioritised according to their level of urgency. No new methods have been developed in the context of the development of this document as the intention was to identify and promote current best practice. However, in some cases adjustments to methods have been made and the characterisation factors have been mapped to the common set of ILCD reference elementary flows.

Note that this document does not include recommendations for weighting across impact categories, or for normalisation within a given category relative to, for example, impacts in a given region.

The recommended LCIA methods and characterisation factors are also made available in electronic form, as dedicated 'LCIA method' data sets in the ILCD data set format (see Annex C for supporting elements).

## B.5. ILCD Handbook – Framework and requirements for Life Cycle Impact Assessment models and indicators

This guidance document provides a framework and sets the requirements for models that are used to quantify environmental impacts. Such models calculate the potential impacts on human health, the natural environment and natural resources that are caused by emissions to air, water and soil, as well as by consumption of material, energy and land resources. Therefore, this document supports experts in the development of LCIA methods and individual impact factors for different impact categories (such as climate change or acidification) for use in LCA.

Over the past 20 years, several methodologies have been developed for LCIA and some efforts have been made towards harmonisation. The ISO 14040 standard series brought some clarity on basic principles, but a comprehensive set of requirements for LCIA methods was still required. Therefore, **this guidance document provides:**

- **Sets of criteria and recommendations against which models and indicators for use in LCIA should be evaluated.** This includes their required scientific qualities (i.e. completeness of scope, environmental relevance, scientific robustness and certainty, documentation, transparency and reproducibility, and applicability) and further aspects

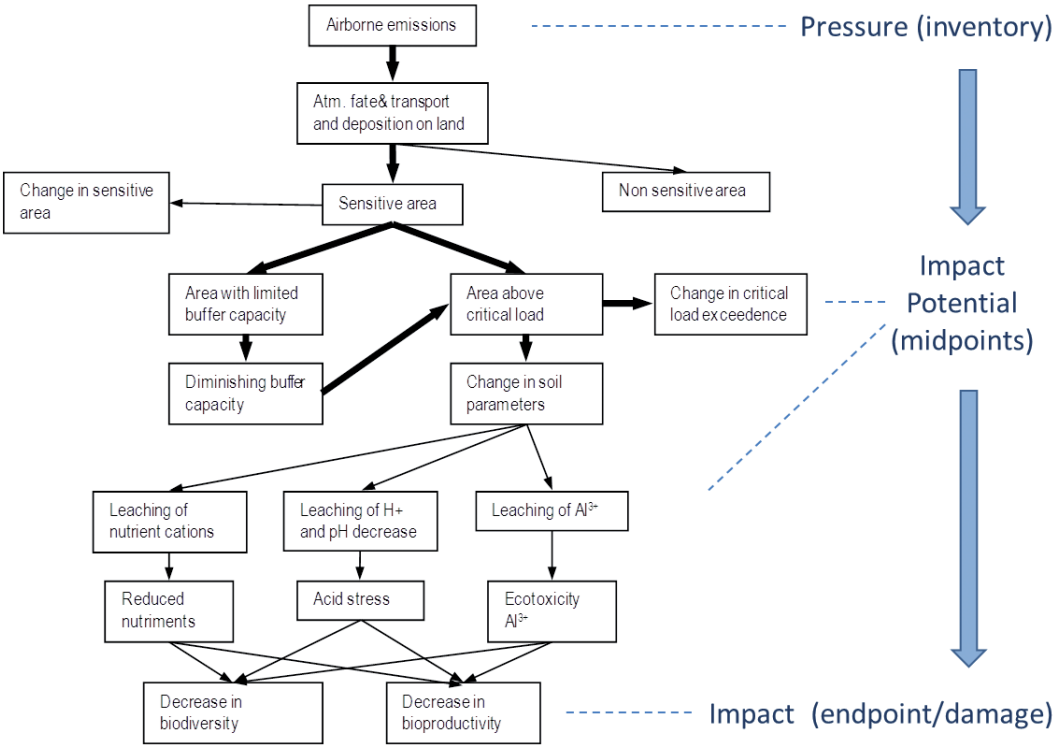


*Figure 11: Cause-effect chain of the impacts of acidification on the natural environment.*

such as international recognition that influence their acceptability to stakeholders.

- **Recommendations for the overall impact assessment framework** for considering a broad range of environmental impacts on the three areas of protection: human health, natural environment and natural resources.

- **A description of the environmental mechanism for each impact category** to provide a common understanding of what needs to be modelled. Taking the example of acidification, such 'cause-effect chains' cover all steps following an acidifying emission to air, from transport, conversion, deposition of the substance to soil, etc., to the increase in the acidity of the soil and the leaching of nutrients, and up to reduced biodiversity and soil bioproductivity (see Figure 11).

- **A set of model requirements** for the environmental impact categories that are commonly addressed in an LCA

This document is supported by the documents on 'Nomenclature and other conventions' (Annex B.9), the 'Terminology' (Annex B.10), the 'Reference data set format' (Annex C.1), and furthermore by the 'Review schemes for Life Cycle Assessment' (Annex B.6).

A **separate background report, the 'ILCD Handbook background document – Analysis of existing Environmental Impact Assessment methodologies for use in Life Cycle Assessment'**, which is not further described in this JRC Reference Report, gives a systematic overview and characterisation of available LCIA methods. This background report served as a basis for developing this 'Framework and requirements' document and the 'Recommendations based on existing environmental impact assessment models and factors for Life Cycle Assessment in a European context' document (see Annex B.4).

### B.6. ILCD Handbook – Review schemes for Life Cycle Assessment

This document defines, through a set of review schemes, the **minimum required types of review for LCA data, studies, selected direct applications of LCA, and ILCD-based specific guides and software tools**. The main target audience of this document are commissioners of developments of LCA data, studies and direct applications.

The principle requirements for reviews are very briefly addressed in ISO 14040 and 14044. While other LCA-related ISO standards define some review requirements in somewhat more detail, none of them provide information on how to conduct the reviews, or on the specific qualifications of the reviewers. Therefore, more specific requirements and guidelines are provided in this document. The overall objective is to strengthen quality assurance of life cycle data and studies and to support the provision of reliable decision support in industry and government. These review schemes balance the cost of reviews with the added value they bring to the policy and market context. The review types outlined in this document can be carried out by, for example, national bodies or private organisations.

Distinctions of the necessary minimum level of review are made for 12 types of LCA activities. The criteria are identified in line with the intended audience of the deliverables (external, technical and non-technical audiences), the complexity and breadth of the case, and the necessity for stakeholder involvement (for example where product comparisons are included in a study). The document also provides provisions on the specific review-related activities, roles and responsibilities.

As a result, only **two review types, 'independent external review' and 'independent panel review', were defined and assigned as the minimum review levels required by each of the 12 types of LCA activities**. Each of these may in addition require the involvement of interested parties/stakeholders. Organisations can request more stringent requirements at their discretion.

This guidance document is complemented by the separate guidance document 'Review scope, methods and documentation' (under development, see Annex B.8), which provides details on carrying out and documenting reviews.

The details and procedure for verifying that a reviewer has the appropriate qualifications are outlined in a separate document entitled 'Reviewer qualification for Life Cycle Inventory data sets' (see Annex B.7). Similar reviewer qualification guidance documents are foreseen for other LCA applications.

### B.7. ILCD Handbook – Reviewer qualification for Life Cycle Inventory data sets

This document specifies the **qualification requirements for reviewers of LCI data sets, as well as the evaluation process to verify the qualification** of the potential reviewer. The target audience of this document are reviewers, LCA study commissioners and system operators.

For a credible review, the qualification and independence of the reviewer(s) is of key importance. None of the LCA-related ISO standards provides detailed information on this. Therefore, more specific requirements are given in this guidance document. This 'qualification' has three components:

- **expertise and application experience in LCA methodology,**
- **knowledge of the applicable review rules and environment-related review or verification experience,**
- **technical expertise in the process, product or other system under analysis in the study that is to be reviewed.**

**'Independence'** relates to independence of the development process of the reviewed data or studies.

Another requirement is that the reviewer be **'external'**. This means that the reviewer may not be employed by or have other relevant links with the organisations involved in the data or studies development, for example as developers or commissioners, or with organisations related to the analysed products (e.g. the industry association representing the product).

In addition to defining qualification requirements for LCI data sets, this guidance document also serves as a starting point for deriving qualification requirements for other types of LCA activities.

Regarding the **qualification recognition and process**, different mechanisms and means of qualification are recognised (e.g. work experience, formal qualifications and experience in conducting reviews or verifications). The aim is to balance clear minimum qualification requirements with flexibility and practicality, ensuring ease of qualification of new experts entering the market.

The level of qualification is evaluated using a **scoring system**. This includes minimum requirements in the three above-mentioned qualification aspects that need to be met. In the case of an individual reviewer alone not meeting all three minimum requirements, 'review teams' of more than one individual expert can be formed to jointly meet the requirements.

The ILCD reviewer qualification can be validated by public authorities or private organisations, known as **system operators**. This can include registries of qualified reviewers. During the establishment phase, however, system operators may implement the reviewer qualification scheme through a **reviewer self-declaration registry**. Such a registry should to be based on the scoring system provided in this guidance document. The preliminary status of such a self-declaration-based registry needs to be clearly communicated to potential users of the registry. An example of such a self-registry system is currently being established by the JRC[44].

### B.8. ILCD Handbook – Review scope, methods and documentation *(under development)*

This guidance document defines a detailed set of provisions on **what to review ('scope of the review') and how ('methods of review')** in LCA. It is differentiated into the 12 different kinds of LCA applications covered by the 'Review schemes for Life Cycle Assessment' document (see Annex B.6). The target audience are reviewers of LCA activities.

The **'scope of review'** relates to the question of which aspect is to be reviewed on which level. For example, whether methodological compliance is checked only in the study report or also in the detailed LCI model.

The **'method of review'** describes how each of the review checks are carried out, e.g. by sample calculations, reading available documentation, or (in extreme cases) when verification of raw data on site or via interviews may be required.

None of the LCA-related ISO standards provides detailed information on the scope/level of review and the review methods to be applied. Therefore, more specific, operational requirements are given in this guidance document, as always in conformity with the ISO standards.

Also, **reporting** of review findings is not addressed in the relevant ISO standards; key guidelines are therefore provided in this guidance document, including an optional review report template.

### B.9. ILCD Handbook – Nomenclature and other conventions

This guidance document guides the **naming and classification of the various basic elements of LCA, such as flows, quantities (flow properties), dimensions (units), processes, contacts and sources**. It supports the development of LCI and LCIA data sets, and the ILCD compliance of LCA studies with respect to their nomenclature.

[44] For the ILCD reviewer self-registry at the JRC, see http://lct.jrc.ec.europa.eu

This guidance document is designed to **make LCA study reports and data set documentation more accessible to practitioners and reviewers**. Moreover, a common nomenclature is **key to technical compatibility and an efficient electronic data exchange among practitioners**, including via the ILCD Data Network. Standard naming conventions are a prerequisite to overcoming the current barriers among different LCA database and software systems and to avoid errors due to manual data transfer/mapping.

This guidance document therefore provides naming conventions for emissions and resources, substance properties, units, processes, products and other basic elements of LCAs. For a number of these basic data elements, it directly defines the names (e.g. for environmental compartments of emissions and resource sources, physical properties and units). For others that are necessarily developed case by case and by the LCA practitioner, clear rules are provided.

This guidance document is complemented by the **ILCD reference elementary flows and other basic data objects** that are provided in the electronic ILCD reference data set format, currently via http://lct.jrc.ec.europa.eu/assessment/publications.

### B.10. ILCD Handbook – Terminology *(under development)*

The 'Terminology' guidance document will provide **hierarchical terms and definitions as well as illustrative examples** of a wide range of technical terms used in LCA. While key basic concepts are defined in ISO 14040 and 14044, many derived concepts have been developed by different groups using different terms and often using slightly different concepts for these terms.

This terminology will provide a **multi-language online system** of a broad set of terms for better compatibility and comprehensibility of LCI data and LCA studies developed by different groups in an international context.

The target audience are experts working in the LCA domain, as well as technical experts and middle management that commission LCA work and receive study reports.

A related **ontology** could be a future step, bridging the different concepts of terms in use.

# ANNEX C: ILCD DATA NETWORK, ILCD-SUPPORTING AND OTHER LCA RESOURCES

## C.1. ILCD Handbook – related and supporting developments

The ILCD Handbook is accompanied by the upcoming ILCD Data Network. Both are supported by a variety of documents, templates, data and software tools. In parallel to developing the ILCD, other online resources that support LCA in general have also been developed at the JRC.

Please note that these developments are not a formal part of the ILCD Handbook. However, when compiling ILCD-compliant data sets, some of these ILCD-supporting elements and resources are to be used to ensure consistency and appropriate documentation.

These supporting elements facilitate the practical implementation of the ILCD Handbook, e.g. documentation of LCA studies or data sets, reporting of reviews or global dissemination of LCI data sets.

### *ILCD-supporting documents and templates*

- **LCA study template;**
- **Documentation of LCA data sets guide**, defining the minimum requirements for appropriately documented ILCD-compliant LCA data sets;
- **Review report template;**
- **ILCD Data Network – Compliance rules and entry-level requirements guide**, summarising the entry-level and ILCD compliance requirements for LCI data sets;
- **Universally Unique Identifiers (UUIDs) and version numbers guide**, documenting certain technical conventions for ILCD formatted data sets.

### *Electronic ILCD resources*

- **ILCD reference elementary flows and other basic data objects** derived from the 'ILCD Handbook – Nomenclature and other conventions' document as a common set of basic data elements for compatible LCI data sets;
- **ILCD data set format**, for condensed yet comprehensive electronic documentation of LCI and LCIA method data sets;
- **ILCD data set editor**, for editing data sets in the ILCD format;
- **ILCD2XLS converter (process data sets)**, for converting ILCD-formatted process data sets from their native XML format to Microsoft Excel;
- **XLS2ILCD converter (LCIA method data sets)** for converting LCIA method data sets from Microsoft Excel to the ILCD format;
- **ILCD data storage engine with Application Programming Interface (API)**, the core of each ILCD Data Network node and hence of the network;
- **Web-based ILCD Data Network search, download and basic data and user access management functions**, the web-interface to the ILCD Data Network;
- **ILCD reviewer self-registry**, for reviewers to document and publicly announce their qualifications in a structured way and show qualification scores according to the 'ILCD Handbook – Reviewer qualification for Life Cycle Inventory data sets' (see Annex B.7).

### C.2. General LCA resources

- **ELCD database**, free-of-charge LCI database with well-documented quality data sets of core materials, energy carriers, transport and waste services in the European market; from European industry associations, as far as possible, and other sources;

- **LCA Resources Directory**, the most comprehensive global directory of life cycle-related service providers, databases, software tools, LCA studies and Type III EPDs;

- **LCT Forum mailing list**, an independent e-mail-based discussion forum for announcing open positions and conferences or to put technical and scientific questions to the other subscribers about EPDs, ecodesign, ecolabels, carbon footprints, life cycle data and methods, and related topics.

Access to these resources and further technical details are available at http://lct.jrc.ec.europa.eu/assessment/publications

# ANNEX D: DOCUMENTS CONSIDERED IN THE ILCD HANDBOOK DEVELOPMENTS

The following documents have been explicitly considered in the development of the various ILCD Handbook documents. (Additional sources have been considered for the supporting documents, templates and tools, which are not within the main scope of this JRC reference report and hence not referenced here.)

## D.1. Related ISO/CEN standards, national specifications and standards


1. ISO 14001:2004 Environmental Management Systems – Requirements with guidance for use.

2. ISO 14004:2004 Environmental Management Systems – General guidelines on principles, systems and support techniques.

3. ISO 14020:2000 Environmental Labels and Declarations – General principles.

4. ISO 14024:1999 Environmental Labels and Declarations – Type I environmental labelling – Principles and procedures.

5. ISO 14025:2006 Environmental Labels and Declarations – Type III environmental declarations – Principles and procedures.

6. ISO 14040:2006 Environmental management – Life cycle assessment – Principles and framework.

7. ISO 14044:2006 Environmental management – Life cycle assessment – Requirements and guidelines.

8. ISO/TR 14062:2002 Environmental management – Integrating environmental aspects into product design and development.

9. CEN/TC 261 SC4 WG1 on "Packaging – LCA" and the CEN/TR 13910 "Packaging – Report on criteria and methodologies for life cycle analysis of packaging (2000)" (under revision).

10. BSI British Standards Institute (2008): PAS 2050 "Specification for the measurement of the embodied greenhouse gas emissions of products and services" on carbon footprinting. And BSI British Standards Institute (with DEFRA and the Carbon Trust) (2008): "Guide to PAS 2050 – How to assess the carbon footprint of goods and services". ISBN 978-0-580-64636-2.

11. AFNOR/ADEME France (2009): General principles for an environmental communication on mass market products. Series: Repository of good practices. BP X 30-323. ISSN 0335-3931. First issue September 2009.


This is a list of the explicitly consulted standards. However, many other ISO and national standards can be of relevance, depending on the application.

## D.2. National LCA database manuals


12. AusLCI and ALCAS: Guidelines for Data Development for an Australian Life Cycle Inventory Database. Committee Draft of 8 July 2008 (http://alcas.asn.au/auslci/pmwiki/uploads/AusLCI/AUSLCI_Data_Guidelines_CD_July08.doc).

13. Danish EPA (editor): Reports of the EDIP guidelines 2003. Environmental Project No 216.6, 862 2003, 863 2003, 70 2004.

14. JEMAI (2002): Japan Environmental Management Association for Industry (JEMAI) data collection manual.

15. Korea: Asia Pacific Economic Cooperation – APEC & Ministry of Commerce, Industry and Energy, Republic of Korea. Lee, K.-M. and Inaba, A. (eds) (2004): Life Cycle Assessment – Best Practices of ISO 14040 Series.

16. NREL (February 2004): US LCI Database Project Development Guidelines. Final draft. NREL/SR-33806 (http://www.nrel.gov/lci/docs/dataguidelinesfinal-rpt1-13-04.doc).

### D.3. Methodological handbooks of industry associations

17. ACE (no year): Guideline on Liquid Packaging Board (LPB) LCI data compilation, version 1.0. Unpublished.

18. EUROFER (2000): European LCI Database for Coiled Flat Stainless Steel Products. Methodology Report. European Confederation of Iron and Steel Industries, Stainless Producers Group. Unpublished.

19. worldsteel/IISI (2002, 2005, 2007): Worldwide LCI Database for Industry Steel Products. Final Methodology Report of the International Iron and Steel Institute. 2002. Updated annex „IISI Recycling methodology", 2005. Plus separate methodology report on recycling modelling methods: Geyer, R. & Bren, D. (2007): "Life Cycle Greenhouse Gas Emission Assessments of Automotive Materials – The Example of Mild Steel, Advanced High Strength Steel and Aluminium in Body in White Applications" (www.worldsteel.org).

20. FEFCO, GEO, ECO (2006): European Database for Corrugated Board Life Cycle Studies. European Federation of Corrugated Board Manufacturers – FEFCO, European Association of makers of Corrugated Base Papers – GEO, European Containerboard Organisation – ECO (www.fefco.org).

21. IAI (2003): Life Cycle Assessment of Aluminium: Inventory Data for the Worldwide Primary Aluminium Industry (www.world-aluminium.org).

22. Boustead, I. (2005): Eco-Profiles of the European Plastics Industry. Methodology. Report for PlasticsEurope, last revision March 2005 (www.plasticseurope.org).

23. DEKRA Umwelt GmbH (2008): PlasticsEurope Eco-profiles and Environmental Declarations – Life Cycle Inventory Methodology and Product Category Rules (PCR) for Uncompounded Polymer Resins and Reactive Polymer Precursors. Final draft. Unpublished.

24. Tikana, L., Sievers, H., Klassert, A. (2005): Life Cycle Assessment of Copper Products. Deutsches Kupferinstitut (DKI) and European Copper Institute (ECI). Unpublished.

### D.4. Major methodological handbooks on LCI and LCA from research and data providers[45]

25. Baumann, H. and Tillman, A.-M. (2004): The Hitch Hiker's Guide to LCA. ISBN: 9144023642.

26. Beaufort-Langeveld, A. et al. (eds) (2001): SETAC Code of Life-Cycle Inventory Practice, 2001. Developed by the former SETAC WG on Data Availability and Quality 1998-2001.

27. Ecobilan (2005): DEAM™ methodical handbook (http://www.ecobilan.com/uk_deam.php).

28. Consoli, F. et al. (1993): Guidelines for Life Cycle Assessment: A Code of Practice. SETAC.

29. Guinée, J.B. (ed.), Gorrée, M., Heijungs, R., Huppes, G., Kleijn, R., de Koning, A., Van Oers, L., Wegener Sleeswijk, A., Suh, S., Udo de Haes, H.A., De Bruijn, J.A., Van Duin R., Huijbregts, M.A.J. (2002): Handbook on Life Cycle Assessment: Operational Guide to the ISO Standards. Series: Eco-efficiency in industry and science. Kluwer Academic Publishers. Dordrecht. ISBN 1-4020-0228-9 (hardback), ISBN 1-4020-0557-1 (paperback).

30. Hauschild, M.Z. and Wenzel, H. (1998): Environmental assessment of products. Vol. 2 – Scientific background. 565 pp. Chapman & Hall, United Kingdom, Kluwer Academic Publishers, Hingham, MA, USA. ISBN 0412 80810 2.

31. LBP University of Stuttgart/PE International (2006): GaBi handbook and GaBi modelling principles (www.gabi-software.com).

[45] A request was sent to a wide range of LCA software and database developers to send their methodological handbooks for consideration for the European handbook development; these were considered if they were made available.

32. Swiss Ecoinvent Centre (2007); Frischknecht, R., Jungbluth, N. (eds), Althaus, H.-J., Doka, G., Dones, R., Heck, T., Hellweg, S., Hischier, R., Nemecek, T., Rebitzer, G., Spielmann, M., Wernet, G. (authors) (2007): Ecoinvent Report No 1: Overview and Methodology for the ecoinvent database v. 2.0. Dübendorf (www.ecoinvent.org).

33. Wenzel, H., Hauschild M.Z., Alting, L. (1997): Environmental assessment of products. Vol. 1 – Methodology, tools and case studies in product development. 544 pp. Chapman & Hall, United Kingdom, Kluwer Academic Publishers, Hingham, MA, USA. ISBN 0 412 80800 5.

### D.5. Explicitly consulted scientific literature

34. Ahbe, S., Braunschweig, A., Müller-Wenk, R. (1990): Methodology for Ecobalances Based on Ecological Optimization. BUWAL (SAFEL) Environment Series No 133, Bern.

35. Alkemade, J.R.M., Wiertz, J., Latour, B. (1996): Kalibratie van Ellenbergs milieuindikatiegetallen aan werkelijk gemeten bodemfaktoren. Report No 711901016. National Institute of Public Health and the Environment (RIVM), Bilthoven, the Netherlands.

36. Amann, M., Cofala, J., Heyes, C., Klimont, Z., Schöpp, W. (1999): The RAINS model: A tool for assessing regional emission control strategies in Europe. Pollution Atmosphérique 20: 41-46.

37. Andersson-Sköld, Y., Grennfelt, P., Pleijel K. (1992): Photochemical Ozone Creation Potentials: A study of Different Concepts. Journal of the Air & Waste Management Association 42 (9): 1152-1158.

38. Babisch, W. (2006): Transportation Noise and Cardiovascular Risk. Review and Synthesis of Epidemiological Studies. Dose-effect Curve and Risk Estimation. Umweltbundesamt, Dessau.

39. Bachmann, T.M. (2006): Hazardous Substances and Human Health: Exposure, Impact and External Cost Assessment at the European Scale. Trace Metals and other Contaminants in the Environment, 8. Elsevier, Amsterdam.

40. Baitz, M. (2002): Die Bedeutung der funktionsbasierten Charakterisierung von Flächen-Inanspruchnahmen in industriellen Prozesskettenanalysen. PhD Thesis, University of Stuttgart. Shaker, Aachen (www.shaker.de).

41. Bare, J.C. (2002): Developing a Consistent Decision-Making Framework by Using the US EPA's TRACI. Systems Analysis Branch, Sustainable Technology Division, National Risk Management; Research Laboratory, US Environmental Protection Agency, Cincinnati, OH, USA (http://www.epa.gov/ORD/NRMRL/std/sab/traci/aiche2002paper.pdf).

42. Bare, J.C., Norris, G.A., Pennington D.W., McKone T. (2003): TRACI, The Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts. Journal of Industrial Ecology 6 (3/4) (http://mitpress.mit.edu/journals/pdf/jiec_6_3_49_0.pdf).

43. Bare, J. C., Hofstetter, P., Pennington, D.W., Udo de Haes, H.A. (2000): Life cycle impact assessment midpoints vs. endpoints: The sacrifices and the benefits. International Journal of Life Cycle Assessment 5(5): 319-326.

44. Bare, J.C., Pennington, D.W., Udo de Haes, H.A. (1999): Life Cycle Impact Assessment Sophistication – International Workshop. International Journal of Life Cycle Assessment 4(5): 299-306.

45. Beaugelin, K. (2006): EDEN, Modelling radiological dose in non-human species: Principles, computerization, and application. Health Physics 90 (5): 485-493.

46. Belfiore, N.M. and Anderson, S.L. (1998): Genetic patterns as a tool for monitoring and assessment of environmental impacts: the example of genetic ecotoxicology. Environmental Monitoring And Assessment 51: 465-479.

47. Bennett, D.H., McKone, T.E., Evans, J.S., Nazaroff, W.W., Margni, M.D., Jolliet, O., Smith, K.R. (2002): Defining Intake fraction. Environmental Science & Technology 36: 207A-211A.

48. Bickham, J.W., Sandhu, S., Hebert, P.D.N., Chikhi, L., Athwal, R. (2000): Effects of chemical contaminants on genetic diversity in natural populations: implications for biomonitoring and ecotoxicology. Mutatation Research 463: 33-51.

49. Bos, U. and Wittstock, B. (2007): Land use methodology. Report to summarize the current situation of the methodology to quantify the environmental effects of land use. Report, Lehrstuhl für Bauphysics, University of Stuttgart.

50. Boyd, J. and Banzhaf, S. (2007): What are ecosystem services? The need for standardized environmental accounting units. Ecological Economics 63: 616-626.

51. Brand, G., Braunschweig, A., Scheidegger, A., Schwank, O. (1998): Weighting in Ecobalances with the Ecoscarcity Method – Ecofactors 1997. BUWAL (SAFEL) Environment Series No 297, Bern.

52. Bruzzi, R., Demou, E., Droz, P., Hellweg, S., Huijbregts, M., Jolliet, O., Langenegger, A., Vernez, D., Meijer, A. (2007): Indoor Exposure Models and their Applicability to LCA. Draft report. UNEP/SETAC Life Cycle Initiative.

53. Carter, W.P. (2000): Updated Maximum Incremental Reactivity scale for regulatory applications. California Air Resources Board, Sacramento, CA, USA.

54. Chapman, P.M. (2008): Environmental risks of inorganic metals and metalloids: a continuing, evolving scientific odyssey. Human and Ecological Risk Assessment 14: 5-40.

55. Chapman, P.M., Wang, F., Janssen, C.R., Goulet, R.R., Kamunde, C.N. (2003): Conducting ecological risk assessments of inorganic metals and metalloids: current status. Human and Ecological Risk Assessment 9: 641-697.

56. Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Naeem, S., Limburg, K., Paruelo, J., O'Neill, R.V., Raskin, R., Sutton, P., van den Belt, M. (1997): The value of the world's ecosystem services and natural capital. Nature 387: 253-260.

57. Cotler, H. and Ortega-Larrocea, M.P. (2006): Effects of land use on soil erosion in a tropical dry forest ecosystem, Chamela watershed, Mexico. Catena 65: 107-117.

58. Cowell, S.J. and Clift, R. (2000): A methodology for assessing soil quantity and quality in life cycle assessment. Journal of Cleaner Production 8: 321-331.

59. Crettaz, P., Pennington, D, Rhomberg, L, Brand, K, Jolliet, O. (2002): Assessing Human Health Response in Life Cycle Assessment using ED10s and DALYs: Part 1- Cancer Effects. International Journal of Risk Analysis 22: 931-946.

60. Crettaz, P., Rhomberg, L., Brand, K., Pennington, D.W., Jolliet, O. (2002): Assessing Human Health Response in Life Cycle Assessment using ED10s and DALYs: Carcinogenic Effects. International Journal of Risk Analysis 22 (5): 929-944.

61. Curran, M. A. (2007): Co-Product and Input Allocation Approaches for Creating Life Cycle Inventory Data: A Literature Review. International Journal of Life Cycle Assessment 12: 65-78.

62. De Groot, R.S. (1992): Functions of nature. Evaluation of nature in environmental planning, management and decision making. Wolters-Noordhoff, the Netherlands.

63. De Gruijl, F.R. and Van der Leun, J.C. (2002): A.2 Lens Opacities and cataract. In: Kelfkens et al. (2002): Ozone layer – climate change interactions; Influence on UV levels and UV related effects. Report No 410200112. National Institute of Public Health and the Environment (RIVM), Bilthoven, the Netherlands.

64. De Schryver, A.M., Brakkee, K.W., Goedkoop, M.J., Huijbregts, M.A.J. (2009): Characterization Factors for Global Warming in Life Cycle Assessment Based on Damages to Humans and Ecosystems. Environmental Science and Technology 43 (6): 1689-1695.

65. De Schryver, A. and Goedkoop, M. (2009a): Climate Change. Chap. 3 in: Goedkoop, M., Heijungs, R., Huijbregts, M.A.J., De Schryver, A., Struijs, J., Van Zelm, R. (2009): ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. Report I: Characterisation, first edition (http://www.lcia-recipe.net).

66. De Schryver, A. and Goedkoop, M. (2009b): Land Use. Chap. 10 in: Goedkoop, M., Heijungs, R., Huijbregts, M.A.J., De Schryver, A., Struijs, J., Van Zelm, R. (2009): ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. Report I: Characterisation, first edition (http://www.lcia-recipe.net).

67. De Zwart, D. and Posthuma, L. (2005): Complex mixture toxicity for single and multiple species: proposed methodologies. Environmenal Toxicology and Chemistry 24: 2665-2676.

68. Derwent, R.G., Jenkin, M.E., Saunders, S.M., Pilling, M.J. (1998): Photochemical ozone creation potentials for organic compounds in Northwest Europe calculated with a master chemical mechanism. Atmospheric Environment 32(14/15): 2429-2441.

69. Dewulf, J. et al. (2007): Cumulative Exergy extraction from the natural environment (CEENE): a comprehensive Life Cycle Impact Assessment Method for resource depletion. Environmental Science & Technology 41(24):8477-83.

70. Donaldson, K., Stone, V., Borm, P.J., Jimenez, L.A., Gilmour, P.S., Schins, R.P., Knaapen, A.M., Rahman, I., Faux, S.P., Brown, D.M., MacNee, W. (2003): Oxidative stress and calcium signaling in the adverse effects of environmental particles (PM10). Free Radical Biology and Medicine 34(11): 1369-1382.

71. Dreicer, M., Tort, V., Manen, P. (1995): ExternE, Externalities of Energy, Vol. 5. Nuclear, Centre d'étude sur l'Evaluation de la Protection dans le domaine nucléaire (CEPN), edited by the European Commission DGXII, Science, Research and Development JOULE, Luxembourg.

72. Ecotech (2001): Ecological Footprinting: Final study. Working Document for the STOA Panel. PE No 297.571/Fin. St. European Parliament, DG Research, Luxembourg.

73. EEA (1998): Biodiversity. Europe's environment: the second assessment. European Environment Agency, Office for Official Publications of the European Communities, Luxembourg. pp. 145-178.

74. Ekvall, T., Tillman; A.-M., Molander, S. (2005): Normative ethics and methodology for life cycle assessment. Journal of Cleaner Production 13: 1225-1234.

75. Frischknecht, R., Braunschweig, A., Hofstetter, P., Suter, P. (2000): Modelling Human Health effects of radioactive releases in Life Cycle Impact Assessment, Environmental Impact Assessment Review 20 (2): 159-189.

76. EPA (1997): Exposure Factors Handbook. US Environmental Protection Agency, National Center for Environmental Assessment, Office of Research and Development (www.epa.gov/ncea/efh).

77. Erzinger, S., Zimmermann, A., Dux-Bruggmann, D., Lauber, S. (2004): Assessment and management of environmental impacts in agriculture. Agroscope FAT Taenikon, Eidgenoessische Forschungsanstalt für Agrarwirtschaft und Landtechnik, Ettenhausen, Switzerland. ISSN 0257-9200.

78. Escher, B.I., Hermens, J.L.M. (2004): Internal exposure: linking bioavailability to effects. Environmental Science & Technology 38: 455A-462A.

79. Feitz, A. and Lundie, S. (2002): Soil Salinisation: A Local Life Cycle Assessment Impact Category. International Journal of Life Cycle Assessment 7(4): 244-249.

80. Fenner, K., Kooijman, C., Scheringer, M., Hungerbuhler, K. (2002): Including transformation products into the risk assessment for chemicals: the case of nonylphenol ethoxylate usage in Switzerland. Environmental Science & Technology 36: 1147-1154.

81. Finnveden, G. (1998): On the possibilities of life-cycle assessment, development of methodology and review of case studies. PhD Thesis, Stockholm University.

82. Finnveden, G. (2008): A world with CO2 caps – Electricity production in consequential assessments. Editorial in: International Journal of Life Cycle Assessment 13: 365-367.

83. Forbes, T.L. and Forbes, V.E. (1993): A critique of the use of distribution based extrapolation models in ecotoxicology. Functional Ecology 7: 249-254.

84. Forster, P., Ramaswamy, V., Artaxo, P., Berntsen, T., Betts, R., Fahey, D.W., Haywood, J., Lean, J., Lowe, D.C., Myhre, G., Nganga, J., Prinn, R., Raga, G., Schulz, M., Van Dorland, R. (2007): Changes in Atmospheric Constituents and in Radiative Forcing. In: Climate Change 2007: The Physical Science Basis IPCC 2007. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

85. Frankl, P., Fullana, P., Kreissig, J. (July 2007): Communication of life cycle information in the building and energy sectors; Reviewed Final Draft version 4.2. Task force 3 of the UNEP/SETAC Life Cycle Initiative, Life Cycle Inventory programme, first phase 2001-2005.

86. Frischknecht, R., Braunschweig, A., Hofstetter, P., Suter, P. (2000): Human health damages due to ionizing radiation in life cycle impact assessment. Environmental Impact Assessment Review 20: 159-189.

87. Frischknecht, R., Steiner, R., Jungbluth, N. (2009): The Ecological Scarcity Method – Eco-Factors 2006: A method for impact assessment in LCA. Federal Office for the Environment (FOEN), Zürich and Bern (http://www.bafu.admin.ch/publikationen/publikation/01031/index.html?lang=en). Further info on the 2006 method can be found at www.umwelt-schweiz.ch/uw-0906-e and http://www.esu-services.ch/cms/index.php?id=ubp06.

88. Frischknecht, R. (2007): Cut-off vs. avoided burden in metals' recycling: in view of environmental sustainability, risk perception and eco-efficiency. Presentation at the 33rd LCA forum, 22 November 2007, Lausanne, Switzerland.

89. Frischknecht, R., Steiner, R., Braunschweig, A., Egli, N., Hildesheimer, G. (2006b): Swiss Ecological Scarcity Method: the new version 2006. Proceedings of the 7th International Conference on EcoBalance, November 2006, Tsukuba, Japan.

90. Frischknecht, R., Steiner, R., Jungbluth, N. (2008): Methode der ökologischen Knappheit – Ökofaktoren 2006. Öbu SR No 28/2008, Bundesamt für Umwelt (BAFU), ÖBU Schweizerische Vereinigung für ökologisch bewusste Unternehmungsführung, Zürich and Bern.

91. Frischknecht, R., Steiner, R., Jungbluth, N. (2006a): Methode der ökologischen Knappheit – Ökofaktoren 2006. ö.b.u. und Bundesamt für Umwelt, Bern.

92. Garnier-Laplace, J. C., Beaugelin-Seiller, K., Gilbin, R., Della-Vedova, C., Jolliet, O., Payet, J. (2008): A Screening Level Ecological Risk Assessment and ranking method for liquid radioactive and chemical mixtures released by nuclear facilities under normal operating conditions. Proceedings of the Bergen conference.

93. Garnier-Laplace, J.C., Della-Vedova, C., Gilbin, R., Copplestone, D., Hingston, J., Ciffroy, P. (2006): First derivation of Predicted-No-Effect Values for freshwater and terrestrial ecosystems exposed to radioactive substances. Environmental Science & Technology 40: 6498-6505.

94. Goedkoop, M. and De Schryver, A. (2008): Fossil Resource. Chap. 13 in Goedkoop, M., Heijungs, R., Huijbregts, M.A.J., De Schryver, A., Struijs, J., Van Zelm, R. (2008): ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. Report I: Characterisation factors, first edition . Ministry of VROM, The Hague (www.vrom.nl) (http://www.lcia-recipe.net).

95. Goedkoop, M. and De Schryver, A. (2009): Mineral Resource. Chap. 12 in Goedkoop, M., Heijungs, R., Huijbregts, M.A.J., De Schryver, A., Struijs, J., Van Zelm, R. (2008): ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. Report I: Characterisation factors, first edition, Ministry of VROM, The Hague (www.vrom.nl) (http://www.lcia-recipe.net).

96. Goedkoop, M and Spriensma, R. (1999): The Eco-indicator 99: A damage oriented method for Life Cycle Impact Assessment Methodology. Ministry of VROM, The Hague, the Netherlands (updated version: www.pre.nl/eco-indicator99).

97. Goedkoop, M., Heijungs, R., Huijbregts, M.A.J., De Schryver, A., Struijs, J., Van Zelm, R. (2008): ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. Report I: Characterisation factors, first edition. Ministry of VROM, The Hague , (www.vrom.nl).

98. Gold, M.R., Stevenson, D., Fryback, D.G. (2002): HALYs and QALYs and DALYs, oh my: Similarities and differences in summary measures of population health. Annual Review of Public Health 23: 115-134.

99. Greco, S., Wilson, A., Spengler, J., Levy, J. (2007): Spatial patterns of mobile source particulate matter emissions-to-exposure relationships across the United States. Atmospheric Environment 41 (5): 1011-1025.

100. Griesshammer, R. and Hochfeld, C. (2009): Position statement on measurement and communication of the product carbon footprint for international standardization and harmonization purposes (http://www.bmu.de/files/pdfs/allgemein/application/pdf/memorandum_pcf_en_bf.pdf, accessed January 2010).

101. Guinée, J.B. and Heijungs, R. (1993): A proposal for the classification of toxic substances within the framework of life cycle assessment of products. Chemosphere 26(10): 1925-1944.

102. Guinée, J.B. (1995): Development of a methodology for the environment life-cycle assessment of products; with a case study on margarines. Thesis, Leiden University.

103. Guinée, J.B., Van Oers, L., de Koning, A., Tamis, W. (2006): Life cycle approaches for Conservation Agriculture – Part I: A definition study for data analysis; Part II: Report of the Special Symposium on Life Cycle Approaches for Conservation Agriculture. SETAC-Europe 16th Annual Meeting, 8 May 2006, The Hague. Research commissioned by Syngenta Crop Protection AG, Basel. CML report 171, Leiden (http://www.leidenuniv.nl/cml/ssp/index.html).

104. Hakoyama, H. and Iwasa, Y. (2000): Extinction risk of a density-dependent population estimated from a time series of population size. Journal of Theoretical Biology 204: 337-359.

105. Hamers, T., Aldenberg, T., Van de Meent, D. (1996): Definition report – Indicator Effects Toxic Substances (Itox) Report No 607128001, National Institute of Public Health and the Environment (RIVM), Bilthoven, the Netherlands.

106. Harbers, J.V., Huijbregts, M.A.J., Posthuma, L., Van de Meent, D. (2006): Estimating the impact of high-production-volume chemicals on remote ecosystems by toxic pressure calculation. Environmental Science & Technology 40: 1573-1580.

107. Hauschild, M. and Potting, J. (2005): Spatial differentiation in life cycle impact assessment – the EDIP2003 methodology. Environmental News No 80. The Danish Ministry of the Environment, Environmental Protection Agency, Copenhagen.

108. Hauschild, M., Huijbregts, M., Jolliet, O., MacLeod, M., Margni, M., Payet, J., Schuhmacher, M., van de Meent, D., McKone, T. (2008): Building a Consensus Model for Life Cycle Impact Assessment of Chemicals: the Search for Harmony and Parsimony. Environmental Science & Technology 42(19): 7032-7037.

109. Hauschild, M.Z. (2005): Assessing environmental impacts in a life cycle perspective. Environmental Science & Technology 39(4): 81A-88A.

110. Hauschild, M.Z. and Wenzel, H. (1998a): Environmental assessment of product. Vol. 2 – Scientific background. Chapman & Hall, United Kingdom, Kluwer Academic Publishers, Hingham, MA, USA. ISBN 0412 80810 2 (figures updated in 2004).

111. Hauschild, M.Z. and Wenzel, H. (1998b): Nutrient enrichment as criterion in the environmental assessment of products. Chap. 5 in: Hauschild, M.Z. and Wenzel, H. (1998): Environmental assessment of products. Vol. 2 – Scientific background. Chapman & Hall, United Kingdom, Kluwer Academic Publishers, Hingham, MA, USA. ISBN 0412 80810 2. 565 pp.

112. Hauschild, M.Z., Huijbregts, M., Jolliet, O., MacLeod, M., Margni, M., van de Meent, D., Rosenbaum, R.K., McKone, T. (2009): Building a Consensus Model for Life Cycle Impact Assessment of Chemicals: the Search for Harmony and Parsimony. Environmental Science and Technology43(6): 1670-1679

113. Hauschild, M.Z., Olsen, S.I., Hansen, E., Schmidt, A. (2008): Gone... but not away – addressing the problem of long-term impacts from landfills in LCA. International Journal of Life Cycle Assessment 13(7): 547-554.

114. Hauschild, M.Z., Potting, J., Hertel, O., Schöpp, W., Bastrup-Birk, A. (2006): Spatial differentiation in the characterisation of photochemical ozone formation – The EDIP2003 methodology. International Journal of Life Cycle Assessment 11(Special Issue 1): 72-80.

115. Hayashi, K., Nakagawa, A., Itsubo, N., Inaba, A. (2006): Expanded Damage Function of Stratospheric Ozone Depletion to Cover Major Endpoints Regarding Life Cycle Impact Assessment. International Journal of Life Cycle Assessment 11: 150-161.

116. Hayashi, K., Okazaki, M., Itsubo, N., Inaba, A. (2004): Development of Damage Function of Acidification for Terrestrial Ecosystems Based on the Effect of Aluminum Toxicity on Net Primary Production. International Journal of Life Cycle Assessment 9(1): 13-22.

117. Heijungs, R. and Guinée, J. B. (2007): Allocation and 'what-if' scenarios in life cycle assessment of waste management systems. Waste Management 27: 997-1005.

118. Hellweg, S. and Frischknecht, R. (2004): Evaluation of Long-Term Impacts in LCA. International Journal of Life Cycle Assessment 9 (5): 339-341.

119. Hellweg, S., Hofstetter, T.B., Hungerbuhler, K. (2003): Discounting and the environment. Should current impacts be weighted differently than impacts harming future generations? International Journal of Life Cycle Assessment 8: 8-18.

120. Hertwich, E., Matales, S.F., Pease, W.S., McKones, T.E. (2001): Human Toxicity Potentials for Life-Cycle Assessment and Toxics Release Inventory Risk Screening. Environmental Toxicology and Chemistry 20: 928-939

121. Hertwich, E., McKone, T., Pease, W. (1999): Parameter uncertainty and variability in evaluative fate and exposure models. Risk Analysis 19: 1193 -1204.

122. Hertwich, E.G., Pease, W.S., Koshland, C.P. (1997): Evaluating the environmental impact of products and production processes: A comparison of six methods. Science of the Total Environment 196: 13-29.

123. Hertwich, E.G., Pease, W.S., McKone, T.E. (1998): Evaluating toxic impact assessment methods: What works best? Environmental Science & Technology 32: A138-A144.

124. Hettelingh, J.P., Posch, M., Slootweg, J., Reinds, G. J., Spranger, T., Tarrason, L. (2007): Critical loads and dynamic modelling to assess European areas at risk of acidification and eutrophication. Water, Air, & Soil Pollution Focus 7: 379-384.

125. Heyes C., Schöpp, W., Amann, M., Unger, S. (1996): A reduced-form model to predict long-term ozone concentrations in Europe. Interim report WP-96-12/December, IIASA, Vienna.

126. Hofstetter, P. (1998): Perspectives in Life Cycle Impact Assessment: A Structured Approach to Combine Models of the Technosphere, Ecosphere and Valuesphere. Kluwer Academic Publishers, Dordrecht, the Netherlands. 484 pp.

127. Hofstetter, P. and Hammitt, J.K. (2002): Selecting human health metrics for environmental decision-support tools. Risk Analysis 22: 965-983.

128. Hofstetter, P. and Müller-Wenk, R. (2005): Monetization of health damages from road noise with implications for monetizing health impacts in life cycle assessment. Journal of Cleaner Production 13: 1235-1245.

129. Hofstetter, P. and Norris, G.A. (2003): Why and how should we assess occupational health impacts in integrated product policy? Environmental Science & Technology 37 (10): 2025-2035.

130. Houghton, J.T., Jenkins, G.J., Ephraums, J.J. (eds) (1990): Climate Change: The IPCC Scientific Assessment IS92a. Cambridge University Press, Cambridge. 365 pp.

131. Huijbregts, M.A.J., Struijs, J., Goedkoop, M., Heijungs, R., Hendriks, A.J., Van de Meent, D. (2005a): Human population intake fractions and environmental fate factors of toxic pollutants in Life Cycle Impact Assessment. Chemosphere 61 (10): 1495-1504.

132. Huijbregts, M.A.J., Rombouts, L.J.A., Ragas A.M.J., Van de Meent, D. (2005): Human-toxicological effect and damage factors of carcinogenic and noncarcinogenic chemicals for life cycle impact assessment. Integrated Environmental Assessment and Management 1: 181-244.

133. Huijbregts, M.A.J., Thissen, U., Guinée, J.B., Jager, T., Van de Meent, D., Ragas, A.M.J., Wegener Sleeswijk, A., Reijnders, L. (2000): Priority assessment of toxic substances in life cycle assessment, I: Calculation of toxicity potentials for 181 substances with the nested multi-media fate, exposure and effects model USES-LCA. Chemosphere 41: 541-573.

134. Huijbregts, M.A.J., Van de Meent, D., Goedkoop, M., Spriensma, R. (2002): Ecotoxicological impacts in life-cycle assessment. In: Posthuma, L., Suter, G.W. II, Traas, T.P. (eds), Species Sensitivity Distributions in Ecotoxicology. Lewis Publishers, Boca Raton, FL, USA. pp. 421-433.

135. Huijbregts, M.A.J. and Van Zelm, R. (2008): Ecotoxicity and human toxicity. Chap. 7 in: Goedkoop, M., Heijungs, R., Huijbregts, M.A.J., Struijs, J., De Schryver, A., Van Zelm, R. (2008):

ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. Report I: Characterisation factors, first edition. Ministry of VROM, The Hague (www.vrom.nl).

136. Huijbregts, M.A.J., Verkuijlen, S.W.E., Heijungs, R., Reijnders, L. (2001): Spatially explicit characterization of acidifying and neutrophying air pollution in life-cycle assessment. Journal of Industrial Ecology 4(3): 75-92.

137. Humbert, S. and Horvath A. UFPM: a modelling tool for size-dependent uptake fractions in the respiratory tract for primary particulate matter. Atmospheric Environment. In preparation.

138. Humbert, S., Horvath, A., Saade, M., Jolliet, O. Effect and characterization factors for primary particulate matter: Re-evaluation incorporating pollutant dynamics. Draft in preparation.

139. Humbert, S., Margni, M., Charles, R., Torres Salazar, O.M., Quirós, A.L. Jolliet, O. (2007): Toxicity Assessment of the most used Pesticides in Costa Rica. Agriculture, Ecosystems & Environment 118 (2007): 183-190.

140. Humbert, S., Shaked, S., Nishioka, Y., Preiss, P., Marshall, J., Stevens, G., Horvath, A. Jolliet, O. Development of consensus characterization factors for primary and secondary particulate matter. In preparation.

141. Humbert, S. Geographically Differentiated Life-cycle Impact Assessment for North America: Influence on Life-cycle Assessment Results for Different Supply Chain Locations, Especially for Fly Ash Concrete. PhD thesis, University of California, Berkeley, CA, USA. In preparation.

142. IER (2008): EcoSense. Institut für Energiewirtschaft und Rationelle Energieanwendung (IER), University of Stuttgart (http://ecosenseweb.ier.uni-stuttgart.de).

143. IPCC (2006): 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Vol. 4. Agriculture, Forestry and Other Land Use (http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html).

144. Itsubo, N. and Inaba, A. (2003): A New LCA Method: LIME has been completed. International Journal of Life Cycle Assessment 8 (5): 305.

145. Itsubo, N. et al. (2008a): LIME documentation. Eutrophication. Chap. 2.8 of draft English translation of LIME documentation (figures and tables still in Japanese).

146. Itsubo, N. et al. (2008b): LIME documentation. Land use. Chap. 2.9 of draft English translation of LIME documentation (figures and tables still in Japanese).

147. Itsubo, N. et al. (2008c): LIME documentation. Ozone layer depletion. Chap. 2.1 of draft English translation of LIME documentation (figures and tables still in Japanese).

148. Itsubo, N. et al. (2008d): LIME documentation. Photochemical oxidants. Chap. 2.5 of draft English translation of LIME documentation (figures and tables still in Japanese).

149. Itsubo, N., Li, R., Abe, K., Nakagawa, A., Hayashi, K., Inaba, A. (2003): Biodiversity Damage Assessment – Applying the Theory of Biology in LCIA. Slides from platform presentation (WE2/8) at the SETAC Europe 13th Annual Meeting, 27 April-1 May 2003, Hamburg, Germany.

150. Itsubo, N., Sakagami, M., Washida, T., Kokubu, K., Inaba, A. (2004): Weighting Across Safeguard Subjects for LCIA through the Application of Conjoint Analysis. International Journal of Life Cycle Assessment 9(3): 196-2005.

151. IVAM, Amsterdam and IKP, Stuttgart. Chap. 4, draft. Task force 2 of the UNEP/SETAC Life Cycle Initiative, Life Cycle Inventory programme, first phase 2001-2005.

152. Jarvinen, O. and Miettinen, K. (1987): Sista paret ut. Naturskyddsforeningen. Miljoforlaget, Sweden.

153. Jensen, A. A., Hoffmann L., Møller B. et al. (1997): Life Cycle Assessment. A guide to approaches, experiences and information sources. Environmental Issues Series No 6. European Environmental Agency, Copenhagen.

154. Jolliet, O., Margni, M., Charles, R., Humbert, S., Payet, J., Rebitzer, G., Rosenbaum, R. (2003): IMPACT 2002+: A New Life Cycle Impact Assessment Methodology. International Journal of Life Cycle Assessment 8 (6): 324-330.

155. Jolliet, O., Müller-Wenk, R., Bare, J. C. , Brent, A., Goedkoop, M., Heijungs, R., Itsubo, N., Peña, C., Pennington, D., Potting, J., Rebitzer, G., Stewart, M., Udo de Haes H., Weidema, B. (2004): The LCIA Midpoint-damage Framework of the UNEP/SETAC Life Cycle Initiative. International Journal of Life Cycle Assessment 9(6): 394-404.

156. Jolliet, O., Shaked, S., Humbert, S. (2006): Comparative Identification of Most Significant Toxics Affecting Human Health. SETAC-Europe, 16th Annual Meeting, May 2006, The Hague, the Netherlands.

157. Kärrman, E. and Jönsson, H. (2001): Including Oxidisation of Ammonia in the Eutrophication Impact Category. International Journal of Life Cycle Assessment 6(1): 29-33.

158. Kemna, R., Van Elburg, M., Li, W., Van Holsteijn, R. (2005): MEEUP – Methodology Report. Final version, 28-11-2005. EC, Brussels.

159. Klepper, O. and Van de Meent, D. (1997): Mapping the Potentially Affected Fraction (PAF) of species as an indicator of generic toxic stress. Report No 607504001. National Institute of Public Health and the Environment (RIVM), Bilthoven, the Netherlands.

160. Koellner, T. and Scholz, R.W. (2007): Assessment of land use impacts on the natural environment. Part 1: An analytical framework for pure land occupation and land use change. International Journal of Life Cycle Assessment 12: 16-32.

161. Köllner, T. (2000): Species-pool Effect Potentials (SPEP) as a yardstick to evaluate land-use impacts on biodiversity. Journal of Cleaner Production 8: 293-311.

162. Köllner, T. (2001): Land Use in Product Life Cycles and its Consequences for Ecosystem Quality. PhD thesis No 2519, University St. Gallen, Switzerland. And Countryside Survey 2000: Survey of Broad Habitats and Landscape features. ISBN: 1 85112 460 8.

163. Köllner, T. and Scholz, R.W. (2008): Assessment of land use impacts on the natural environment. Part 2: Generic characterization factors for local species diversity in Central Europe. International Journal of Life Cycle Assessment 13(1): 32-48.

164. Krewitt, W., Mayerhofer, P., Trukenmüller A., Friedrich, R. (1998): Application of the impact pathway analysis in the context of LCA. International Journal of Life Cycle Assessment 3(2): 86-94.

165. Krewitt, W., Pennington, D., Olsen, S.I., Crettaz, P., Jolliet, O. (2002): Indicators for human toxicity in life cycle impact assessment. Chap. 5 in: Udo de Haes, H.A. et al. (eds), Life-cycle impact assessment: Striving towards best practice. SETAC, Pensacola, FL, USA.

166. Krewitt, W., Trukenmüller, A., Bachmann, T.M., Heck, T. (2001): Country-specific damage factors for air pollutants. A step towards site dependent life cycle impact assessment. International. Journal of Life Cycle Assessment 6(4): 199-210.

167. Kros, J. (2002): Evaluation of Biogeochemical Models at Local and Regional Scale. Wageningen University, Wageningen, the Netherlands.

168. Lande, R. (1998): Anthropogenic, ecological and genetic factors in extinction and conservation. Researches on population ecology 40(3): 259-269.

169. Laplace, J., Beaugelin-Seiller, K., Payet, J. Gilbin, R., Jolliet, O. (2007): A screening level risk assessment and ranking method for chemical and radioactive mixtures released in freshwaters by nuclear facilities under normal operating conditions. Poster MO PC7-2, SETAC NA, Milwaukee, WI, USA.

170. Larsen, H.F. and Hauschild, M.Z. (2007): Evaluation of ecotoxicity effect indicators for use in LCIA. International Journal of Life Cycle Assessment 12(1): 24-33.

171. Leske, T. and Buckley, C. (2003): Towards the development of a salinity impact category for South African environmental life-cycle assessments: Part 1 – A new impact category. Water SA, 29 (3): 289-296.

172. Leske, T. and Buckley, C. (2004a): Towards the development of a salinity impact category for South African life cycle assessments: Part 2 – A conceptual multimedia environmental fate and effect model. Water SA 30 (2): 241-251.

173. Leske, T. and Buckley, C. (2004b): Towards the development of a salinity impact category for South African life cycle assessments: Part 3 – Salinity potentials. Water SA 30 (2): 253-265.

174. Levy, J.I., Wolff, S., Evans, J.S. (2002): A regression-based approach for estimating primary and secondary particulate matter exposure efficiency. Risk Analysis 22(5): 895-904.

175. Lindeijer, E., Muller-Wenk, R., Steen, B. (2002): Impact assessment on resources and land use. In: Udo de Haes, H.A. et al. (eds), Life-cycle impact assessment: Striving towards best practice. SETAC, Pensacola, FL, USA.

176. Lindfors, L.-G., Christiansen, K., Hoffman, L., Virtanen, Y., Juntilla, V., Hanssen, O.-J., Rönning, A., Ekvall, T., Finnveden, G. (1995): Nordic Guidelines on Life-Cycle Assessment. Nordic Council of Ministers, Copenhagen.

177. Lundie, S., Ciroth, A., Huppes, G. (June 2007): Inventory methods in LCA: towards consistency and improvement. Final report. UNEP/SETAC Life Cycle Initiative, Life Cycle Inventory Programme, first phase 2001-2005.

178. MacLeod, M., Woodfine, D.G., Mackay, D., McKone, T.E., Bennett, D.H., Maddalena, R. (2001): BETR North America: A regionally segmented multimedia contaminant fate model for North America. Environmental Science and Pollution Research 8: 156-163.

179. Margni, M., Gloria, T., Bare, J., Seppälä, J., Steen, B., Struijs, J., Toffoletto, L., Jolliet, O. (2007): Guidance on how to move from current practice to recommended practice in Life Cycle Impact Assessment: Draft report, UNEP/SETAC Life Cycle Initiative, Life Cycle Impact Assessment Programme.

180. Margni, M., Lesage, P., Michaud R., Belley, C., Clément, E., Samson, R. (2008): Presentation at LCM2009 on "Extending System Boundaries to Capture Indirect Effects on LCA – An Enlightening Example!" (http://www.lcm2009.org/presentations/OR19%20-%20Margni.pdf, accessed October 2009).

181. Marshall, J.D., Teoh, S.K., Nazaroff, W.W. (2005): Intake fraction of nonreactive vehicle emissions in US urban areas. Atmospheric Environment 39: 1363-1371.

182. Mathers, C.D., Bernard, C., Moesgaard Iburg, K., Inoue, M., Ma Fat, D., Shibuya, K., Stein, C., Tomijima, N., Xu, H. (2003): Global Burden of Disease in 2002: data sources, methods and results. Global Programme on Evidence for Health Policy Discussion Paper No 54, World Health Organization (revised February 2004).

183. Mattsson, B., Cederberg, C., Blix, L. (2000): Agricultural land use in life cycle assessment (LCA): case studies of three vegetable oil crops. Journal of Cleaner Production 8: 283-292.

184. McAlearney, A.S., Schweikhart, S.B., Pathak, D.S. (1999): Quality-adjusted life-years and other health indices: a comparative analysis. Clinical Therapeutics 21 (9): 1605-1629.

185. McKone, T., Bennett, D., Maddalena, R. (2001): CalTOX 4.0 Technical Support Document, Vol. 1. LBNL – 47254, Lawrence Berkeley National Laboratory, Berkeley, CA, USA.

186. McMichael, A.J., Campbell-Lendrum, D.H., Corvalan, C.F., Ebi, K.L., Githeko, A., Scheraga, J.D., Woodward, A., (2003): Climate change and human health. Risk and responses. World Health Organization, Geneva. 322 pp.

187. Meadows, D., Meadows, D., Randers, J. (2004): Limits to Growth: The 30-Year Update. Chelsea Green Publishing Company, White River Junction, VT, USA.

188. Meijer, A., Huijbregts, M.A.J., Hertwich, E.G., Reijnders, L. (2006): Including Human Health Damages due to Road Traffic in Life Cycle Assessment of Dwellings. International Journal of Life Cycle Assessment 11 (Special issue 1): 64-71.

189. Meijer, A., Huijbregts, M.A.J., Reijnders L. (2005): Human Health Damages due to Indoor Sources of Organic Compounds and Radioactivity in Life Cycle Impact Assessment of Dwellings. Part 1: Characterisation Factors. International Journal of Life Cycle Assessment 10 (5): 309-316.

190. Meinshausen, M., (2005): Emission & Concentration Implications of long-term Climate Targets, Dissertation 15946 for the Swiss Federal Institute of Technology, Zurich.

191. Metz, B. et al. (eds.) (2005): Special Report on Safeguarding the Ozone Layer and the Global Climate System: Issues Related to Hydrofluorocarbons and Perfluorocarbons IPCC/TEAP, Cambridge University Press,

Cambridge, United Kingdom and New York, NY, USA. 488 pp.

192. Milà i Canals, L., Muñoz, I., McLaren, S.J., Brandão, M. (2007c): LCA Methodology and Modelling Considerations for Vegetable Production and Consumption. CES Working Papers 02/07 (available from http://www.ces-surrey.org.uk).

193. Milà i Canals, L., Romanyà, J., Cowell, S.J. (2007b): Method for assessing impacts on life support functions (LSF) related to the use of 'fertile land' in Life Cycle Assessment (LCA). Journal of Cleaner Production 15: 1426-1440.

194. Milà i Canals, L., Bauer, C., Depestele, J., Dubreuil, A., Knuchel, R.F., Gaillard, G., Michelsen, O., Müller-Wenk, R., Rydgren, B. (2007a): Key elements in a framework for land use impact assessment within LCA. International Journal of Life Cycle Assessment 12(1): 5-15.

195. Milà i Canals, L., Müller-Wenk, R., Bauer, C., Depestele, J., Dubreuil, A. Knuchel, R.F., Gaillard, G., Michelsen, O., Rydgren, B. (2007b): Key elements in a framework for land use impact assessment within LCA. International Journal of Life Cycle Assessment 12(1): 2-4.

196. Mooney, H.A., Lubchenco, J. et al. (1995): Biodiversity and ecosystem functioning: basic principles. Global Biodiversity Assessment. UNEP. Cambridge University Press. Cambridge, UK, pp. 275-325.

197. Müller-Wenk, R. (1994): The Ecoscarcity Method as a Valuation Instrument within the SETAC Framework. In: Udo de Haes, H.A., Jensen, A.A., Klöpffer, W., Lindfors, L-G. (eds): Integrating Impact Assessment into LCA. SETAC-Europe, Brussels. pp. 115-120.

198. Müller-Wenk, R. (1996): Damage categories and Damage functions as Core Elements of Life-Cycle Impact Assessment; IWOE Diskussionsbeitrag No 36 (Draft version 29.10.1996). Institute for Economy and the Environment (IWOE), University of St. Gallen, Switzerland.

199. Müller-Wenk, R. (1998): Depletion of abiotic resources weighted on base of "virtual" impacts of lower grade deposits used in future. IWOE Diskussionsbeitrag No 57. Institute for Economy and the Environment (IWOE), University of St. Gallen, Switzerland.

200. Müller-Wenk, R. (1998a): Land use – The main threat to species. How to include land use in LCA. Institute for Economy and the Environment (IWO), University St. Gallen, Switzerland.

201. Müller-Wenk, R. (2002): Attribution to road traffic of the impact of noise on health. Environmental Series No 339. Swiss Agency for the Environment, Forests and Landscape, Bern.

202. Müller-Wenk, R. (2004): A Method to Include in LCA Road Traffic Noise and its Health Effects. International Journal of Life Cycle Assessment 9 (2): 76-85.

203. Murray, C.J.L. and Lopez, A.D. (1996): The global burden of disease: a comprehensive assessment of mortality and disability from diseases, injuries, and risk factors in 1990 and projected to 2020. Global Burden of Disease and Injury Series, Vol. I. Harvard School of Public Health, World Bank, World Health Organization, USA. 990 pp.

204. Muys, B. and Garcia Quijano, J. (2002): A new method for Land Use Impact Assessment in LCA based on ecosystem exergy concept. Internal report. Laboratory for Forest, Nature and Landscape Research, KU Leuven, Belgium.

205. Narita, N., Nakahara, Y., Morimoto, M., Aoki, R., Suda, S. (2004): Current LCA Database Development in Japan – Results of the LCA Project. International Journal of Life Cycle Assessment 9 (6): 355-359.

206. Nishioka, Y., Levy, J.I., Norris, G.A., Wilson, A., Hofstetter, P., Spengler, J.D. (2002): Estimating the public health benefits of increased residential insulation for new housing. Risk Analysis 22(5): 1003-1017.

207. The International EPD Cooperation (IEC) (2007): General programme instructions for an International EPD® system for environmental product declarations. Draft Version 0.3, dated 9 November 2007 (http://www.environdec.com/en/The-EPD-system/Programme-Instructions/).

208. NN (2003): Meeting minutes of the International Workshop on Quality of LCI Data, 2003, FZK, Karlsruhe, Germany (http://www.netzwerk-lebenszyklusdaten.de/cms/webdav/site/lca/shared/Veranstaltungen/2003LciWorkshop/Minutes_of_the_quality_workshop.pdf).

209. Norberg, J., Swaney, D.P., Dennis, P., Dushoff, J., Lin, J., Casagrandi, R., Levin, S.A. (2001): Phenotypic diversity and ecosystem functioning in changing environments: A theoretical framework. Proceedings of the National Academy of Sciences (PNAS) 98(20): 11376-11381.

210. Nordhaus, W.D. (1994): The ‚DICE' Model: Background and Structure of a Dynamic Integrated Climate-Economy Model of the Economics of Global Warming. Cowles Foundation Discussion Paper. Cowles Foundation for Research in Economics, New Haven, CT, USA.

211. Norris, G. (2002): Impact characterisation in the tool for the reduction and assessment of chemical and other environmental impacts: Methods for acidification, eutrophication, and ozone formation. Journal of Industrial Ecology 6(3/4): 83-105.

212. Norris, G.A. (2003): Impact Characterization in the Tool for the Reduction and Assessment of Chemical and other Environmental Impacts: Methods for Acidification, Eutrophication, and Ozone Formation. Journal of Industrial Ecology 6 (3/4): 79-101.

213. Owens, J.W., (2002): Chemical toxicity indicators for human health: case study for classification of chronic noncancer chemical hazards in life-cycle assessment. Environmental Toxicology and Chemistry 21 (1): 207-225.

214. Payet, J. (2004): Assessing toxic impacts on aquatic ecosystems in Life Cycle Assessment. Doctoral thesis 3112, École Polytechnique Fédérale de Lausanne, Switzerland. pp. 214.

215. Payet, J. (2006): Deliverable D.4.1.4 to the NOMIRACLE project. Report describing a method for the quantification of impacts on aquatic freshwater ecosystems resulting from different stressors (e.g. toxic substances, eutrophication, etc). École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland.

216. Pehnt, M. (2006): Dynamic life cycle assessment (LCA) of renewable energy technologies. Renewable Energy 31: 55-71.

217. Pennington, D.W., Margni, M., Payet, J., Jolliet, O. (2006): Risk and Regulatory Hazard-Based Toxicological Effect Indicators in Life-Cycle Assessment (LCA). Human and Ecological Risk Assessment 12: 450-475.

218. Pennington, D.W., Crettaz, P., Tauxe, A., Rhomberg, L., Brand, K., Jolliet, O. (2002): Assessing Human Health Response in Life Cycle Assessment Using ED10s and DALYs: Part 2 – Noncancer Effects. Risk Analysis 22 (5): 947-963.

219. Pennington, D.W., Margni, M., Amman, C., Jolliet, O. (2005): Multimedia Fate and Human Intake Modeling: Spatial versus Non-Spatial Insights for Chemical Emissions in Western Europe. Environmental Science & Technology 39 (4): 1119-1128.

220. Pennington, D.W., Payet, J., Hauschild, M.Z. (2004): Aquatic ecotoxicological indicators in life-cycle assessment. Environmental Toxicology and Chemistry 23: 1796-1807.

221. Policy Analysts Ltd RPA (2007): A review of recent developments in, and the practical use of, ecological footprinting methodologies: A research report completed for the Department for Environment, Food and Rural Affairs (http://www.defra.gov.uk/science/project_data/DocumentLibrary/EV02024/EV02024_5880_FRP.pdf).

222. Pope, C.A., Burnett R.T., Thun, M.J., Calle, E.E., Krewski,D., Ito, K., Thurston, G.D. (2002): Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. Journal of the American Medical Association 287: 1132-1141.

223. Posch, M., Seppälä, J., Hettelingh, J.P., Johansson, M., Margni M., Jolliet, O. (2008): The role of atmospheric dispersion models and ecosystem sensitivity in the determination of characterisation factors for acidifying and eutrophying emissions in LCIA. International Journal of Life Cycle Assessment. Submitted.

224. Posthuma, L. and De Zwart, D. (2006): Fish community responses in the field show the empirical meaning of the potentially affected fraction of species as a relative measure of mixture risk. Environmental Toxicology and Chemistry 25: 1094-1105.

225. Potting, J. and Hauschild, M. (2005): Spatial differentiation in life cycle impact assessment – the EDIP2003 methodology. Environmental News No 80. The Danish Ministry of the Environment, Environmental Protection Agency, Copenhagen.

226. Potting, J., Preiss, P., Seppälä, J., Struijs, J., Wiertz, J., Blazek, M., Heijungs, R., Itsubo, N., Masanet, E., Nebel, B., Nishioka, Y., Payet, J., Becaert, V., Basset-Mens, C., Jolliet, O. (2007): Current Practice in LCIA of Transboundary Impact Categories. Report of Task force 4 on transboundary impacts. Life Cycle Impact Assessment Programme, UNEP/SETAC Life Cycle Initiative. pp. 49.

227. Potting, J., Schöpp, W., Blok, K., Hauschild, M.Z. (1998a): Comparison of the acidifying impact from emissions with different regional origin in life-cycle assessment. Journal of Hazardous Materials 61(1-3): 155-162.

228. Potting, J., Schöpp, W., Blok, K., Hauschild, M.Z. (1998b): Site-Dependent Life-Cycle Impact Assessment. Journal of Industrial Ecology 2(2): 63-87.

229. Potting, J., Trukenmüller, A., Christensen, F.M., Van Jaarsveld, H., Olsen, S.I., Hauschild, M.Z. (2005): Human toxicity. Chap. 8 in: Hauschild, M.Z. and Potting, J. (2005): Spatial differentiation in life cycle impact assessment – the EDIP2003 methodology. Environmental News No 80. The Danish Ministry of the Environment, Environmental Protection Agency, Copenhagen.

230. Rabl, A. and Spadaro, J.V. (2004): The RiskPoll software, version is 1.051 (dated August 2004). www.arirabl.com.

231. Reap, J., Roman, F., Duncan, S., Bras, B. (2008): A survey of unresolved problems in life cycle assessment. Part 1: goal and scope and inventory analysis. International Journal of Life Cycle Assessment 13(4): 290-300.

232. Rees, W. E. (1992): "Ecological footprints and appropriated carrying capacity: what urban economics leaves out". Environment and Urbanisation 4(2). Available from Sage Journals Online (http://eau.sagepub.com/cgi/reprint/4/2/121).

233. Rhodes, S. et al. (2006): LCSEA MODEL: Procedures for Calculating Specific Impact Indicators. Annex 1 of ASTM draft standard on Standard Practice for Comparing the Environmental Performance of the Electric Power Generation Facilities and Infrastructure (http://standards.nsf.org/apps/group_public/download.php/5414/ASTMLCIASTDFinal07-07-06.pdf).

234. Rochat, D., Margni, M., Jolliet, O. (2006): Continent-Specific Characterization Factors and Intake Fractions for Toxic Emissions: Does it make a Difference? International Journal of Life Cycle Assessment 11 (Special issue 1): 55-63.

235. Ron, E. and Muirhead, C. (1998): The carcinogenic effects of ionizing radiation: epidemiological evidence. In: Low Doses of Ionizing Radiation: Biological Effects and Regulatory Control. Proceedings of a Conference, Seville, Spain, 17-21 November 1997. IAEA and WHO, Vienna. pp. 165-80.

236. Rosenbaum, R. (2006): Multimedia and food chain modelling of toxics for comparative risk and life cycle impact assessment. Thesis 3539, Chap. 5 on Uncertainties, École Polytechnique Fédérale de Lausanne, Switzerland.

237. Rosenbaum, R., Margni, M., Jolliet, O. (2007a): A flexible matrix algebra framework for the multimedia multipathway modeling of emission to impacts. Environment International 33 (5): 624-634.

238. Rosenbaum, R.K., Bachmann, T.M., Gold, L.S., Huijbregts, M.A.J., Jolliet, O., Juraske, R., Köhler, A., Larsen, H.F., MacLeod, M., Margni, M., McKone, T.E., Payet, J., Schuhmacher, M., van de Meent, D., Hauschild, M.Z. (2008): USEtox – The UNEP/SETAC toxicity model: recommended characterisation factors for human toxicity and freshwater ecotoxicity in Life Cycle Impact Assessment. International Journal of Life Cycle Assessment 13(7): 532-546.

239. Rutishauser, B. V., Pesonen, M., Escher, B. I., Ackermann, G. E., Aerni, H.-R., Suter, M. J.-F., Eggen, R. I. L. (2004): Comparative Analysis of Estrogenic Activity in Sewage Treatment Plant Effluents Involving Three In Vitro Assays and Chemical Analysis of Steroids. Environmental Toxicology and Chemistry 23: 857-868.

240. Sanden, B.A. and Karlström, M. (2007): Positive and negative feedback in consequential life-cycle assessment. Journal of Cleaner Production 15: 1469-1481.

241. Sasaki, K., Sasaki, H., Kojima, M., Shui, Y.B., Hockwin, O., Jonasson, F., Cheng, H.M., Ono, M., Katoh, N. (1999): Epidemiological Studies on UV-Related Cataract in Climatically Different Countries. Journal of Epidemiology 9: S33-S38.

242. Schere, K.L. and Demerjian, K.L. (1984): User's guide for the photochemical box model (PBM). EPA-600/8-84-022a. Environmental Protection Agency, USA.

243. Schimel, D., Alves, D., Enting, I. et al. (1996): Radiative forcing of Climate Change, IPCC model IS92a, in: Houghton, J.T., Meira Filho, L.G., Collander, B.A. et al. (eds), Climate Change 1995: The Science of Climate Change, Working Group I of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK.

244. Selck, H., Riemann, B., Christoffersen, K., Forbes, V.E., Gustavson, K., Hansen, B.W., Jacobsen, J.A., Kusk, K.O., Petersen, S. (2002): Comparing Sensitivity of Ecotoxicological Effect Endpoints between Laboratory and Field. Ecotoxicology and Environmental Safety 52: 97-112.

245. Seppälä, J., Posch, M., Johansson, M., Hettelingh, J.P. (2006): Country-Dependent Characterisation Factors for Acidification and Terrestrial Eutrophication Based on Accumulated Exceedance as an Impact Category Indicator. International Journal of Life Cycle Assessment 11 (6): 403-416.

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

247. Steen, B (1999b): 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, Gothenburg, Sweden.

248. Steen, B. (2006): Abiotic resource depletion, different perception of the problem with mineral deposits. International journal of Life Cycle Assessment 11 (Special issue 1): 49-54.

249. Stewart, M. and Weidema, B. (2005): A consistent framework for assessing the impacts from resource use, a focus on resource functionality. International journal of Life Cycle Assessment 10(4): 240-247.

250. Stoeser, D.B. and Heran, W.D. (eds) (2000): USGS Mineral deposit models. USGS Digital Data Series DDS-064, US Geological Survey, Denver, CO, USA.

251. Stranddorf, H., Hoffmann, L., Schmidt, A. (2005): Impact categories, normalisation and weighting in LCA. Environmental News No 78. The Danish Ministry of the Environment, Environmental Protection Agency, Copenhagen.

252. Struijs, J., Van Dijk, A., Van Wijnen, H.J., Velders, G.J.M., Huijbregts, M.A.J. (2010): Spatial- and Time-Explicit Human Damage Modeling of Ozone Depleting Substances in Life Cycle Impact Assessment. Environmental Science & Technology 44(1): 204-209

253. Struijs, J., Beusen, A., van Jaarsveld, H., Huijbregts, M.A.J. (2008b): Aquatic Eutrophication. Chap. 6 in: Goedkoop, M., Heijungs, R., Huijbregts, M.A.J., De Schryver, A., Struijs, J., Van Zelm, R. (2008). ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. Report I: Characterisation factors, first edition. Ministry of VROM, The Hague (www.vrom.nl).

254. Struijs, J., van Wijnen, H.J., van Dijk, A., Huijbregts, M.A.J. (2008a): Ozone layer depletion. Chap. 4 in: Goedkoop, M., Heijungs, R., Huijbregts, M.A.J., De Schryver, A., Struijs, J., Van Zelm, R. (2008). ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. Report I: Characterisation factors, first edition. Ministry of VROM, The Hague (www.vrom.nl).

255. Tanaka, Y. and Nakanishi, J. (2000): Mean extinction time of population under toxicant stress and ecological risk assessment. Environmental Toxicology and Chemistry 19(11): 2856-2862.

256. Tarrason, L., Fagerli, H., Klein, H., Simpson, D., Benedictow, A., Vestreng, V., Riegler, E., Emberson, L., Posch, M., Spranger T. (2006): Transboundary acidification, eutrophication and ground level ozone in Europe from 1990 to 2004 in support for the review of the Gothenburg protocol. Norwegian Meteorological Institute, Oslo, Norway.

257. Thomas, C.D., Cameron, A., Green, R.E., Bakkenes, M., Beaumont, L.J., Collingham, Y.C., Erasmus, B.F.N., Ferreira de Siqueira, M., Grainger, A. (2004): Extinction risk from climate change. Nature 427 (6970): 145-147.

258. Thompson, M., Ellis R., Wildavsky A. (1990): Cultural Theory. Westview Press, Westport, CO, USA.

259. Tilman, D. (2001): An evolutionary approach to ecosystem functioning. Proceedings of the National Academy of Sciences (PNAS) 98(20): 10979-10980.

260. Toffoletto, L. Bulle, C., Godin, J., Reid C., Deschênes, L. (2007): LUCAS – A New LCIA Method Used for a Canadian-Specific Context. International Journal of Life Cycle Assessment 12(2): 93-102.

261. Tol, R.S.J. (1999): The Marginal Costs of Greenhouse Gas Emissions. The Energy Journal 20 (1): 61-81.

262. Tørsløv, J., Hauschild, M.Z., Rasmussen, D. (2005): Ecotoxicity. In: Potting, J. and Hauschild, M.Z. (eds.) Spatial Differentiation in Life Cycle Impact Assessment – The EDIP2003 Methodology. Environmental News No 80. The Danish Ministry of the Environment, Environmental Protection Agency, Copenhagen.

263. Udo de Haes, H.A., Finnveden, G., Goedkoop, M., Hauschild, M.Z., Hertwich, E.G., Hofstetter, P., Jolliet, O., Klöpffer, W., Krewitt, W., Lindeijer, E., Mueller-Wenk, R., Olsen, I., Pennington, D.W., Potting, J., Steen, B. (2002): Life-Cycle Impact Assessment: Striving towards Best Practice. SETAC. ISBN 1-880661-64-6.

264. Udo de Haes, H.A., Jolliet, O., Finnveden, G., Hauschild, M.Z., Krewitt, W., Müller-Wenk, R. (1999): Best Available Practice Regarding Impact Categories and Category Indicators in Life Cycle Impact Assessment. International Journal of Life Cycle Assessment 4(2): 66-74.

265. UNSCEAR (1993): United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (ed.). Sources and Effects of Ionizing Radiation. Report to the General Assembly, with Scientific Annexes. United Nations, New York.

266. Van de Meent, D. and Huijbregts, M.A.J. (2005): Calculating life-cycle assessment effect factors from potentially affected fraction-based ecotoxicological response functions. Environmental Toxicology and Chemistry 24: 1573-1578.

267. Van der Voet, E. (2001): Land use in LCA. CML-SSP working paper 02.002.

268. Van Dijk, A., Den Outer, P., Van Wijnen, H., Slaper, H. (2007): Manual of AMOUR 2.0: Assessment Model for Ultraviolet Radiation and Risks. Report No 410 200.7

269. Van Jaarsveld, J.A., Van Pul, W.A.J., De Leeuw, F.A.A.M. (1997): Modelling transport and deposition of persistent organic pollutants in the European region. Atmospheric Environment 7: 1011-1024.

270. Van Oers, L. (ed.), Huijbregts, M.A.J., Huppes, G., de Koning, A., Suh, S. (2001): LCA normalisation factors for the Netherlands, Europe and the World. RIZA werkdocument 2001.059x.

271. Van Oers, L., De Koning, A., Guinée, J.B., Huppes G. (2002): Abiotic resource depletion in LCA – Improving characterization factors for abiotic resource depletion as recommended in the new Dutch LCA Handbook. Published by Road and Hydraulic Engineering Institute of the Dutch Ministry of Transport, Public Works and Water Management (V&W). 75 pp.

272. Van Straalen, N.M. and Timmermans, M.J.T.N. (2002): Genetic Variation in Toxicant-Stressed Populations: An Evaluation of the „Genetic Erosion" Hypothesis. Human and Ecological Risk Assessment 8(5): 983-1002.

273. Van Zelm, R., Huijbregts, M.A.J., Den Hollander, H.A., Van Jaarsveld, H.A., Sauter, F.J., Struijs, J., Van Wijnen, H.J., Van de Meent, D. (2008): European characterization factors for respiratory health damage due to PM10 and ozone in life cycle impact assessment. Atmospheric Environment 42 (3): 441-453.

274. Van Zelm, R., Huijbregts, M.A.J., Wintersen, A., Posthuma, L., Van de Meent, D. (2009): Pesticide ecotoxicological effect factors and their uncertainties for freshwater ecosystems. International Journal of Life Cycle Assessment 14 (1): 43-51

275. Van Zelm, R., Huijbregts, M.A.J., Harbers, J.V., Wintersen, A., Struijs, J., Posthuma, L., Van de Meent, D. (2007): Uncertainty in msPAF-based ecotoxicological freshwater effect factors for chemicals with a non-specific mode of action in life cycle impact assessment. Integrated Environmental Assessment and Management 3 (2): 203-210.

276. Van Zelm, R., Huijbregts, M.A.J., Van Jaarsveld, H.A., Reinds, G.J., De Zwart, D., Struijs, J., Van de Meent, D. (2007): Time horizon dependent characterisation factors for acidification in life-cycle impact assessment based on the disappeared fraction of plant species in European forests. Environmental Science & Technology 41: 922-927.

277. Van Zelm, R., Huijbregts, M.A.J., Den Hollander, H.A., Van Jaarsveld, H.A., Sauter, F.J., Struijs, J., Van Wijnen, H.J., Van de Meent, D. (2008): European characterization factors for human health damage of PM10 and ozone in life cycle impact assessment. Atmospheric Environment 42: 441-453.

278. Wackernagel, M., Monfreda, C., Moran, D., Wermer, P., Goldfinger, S., Deumling, D., Murray, M. (2005): National Footprint and Biocapacity Accounts 2005: The underlying calculation method. Global Footprint Network, Oakland, CA, USA.

279. Wegener Sleeswijk, A., Van Oers, L., Guinée, J., Struijs, J., Huijbregts, M.A.J. (2008): Normalisation in product life cycle assessment: An LCA of the global and European economic systems in the year 2000. Science of the Total Environment 390 (1): 227-240.

280. Weidema, B. (2003): Market information in life cycle assessment. Environmental Project No 863 2003. Danish Environmental Protection Agency, Copenhagen.

281. Weidema, B., Cappellaro, F., Carlson, R., Notten, P., Pålsson, A.-C., Patyk, A., Regalini, E.;,Sacchetto, F., Scalbi, S. (2004): Procedural guideline for the collection, treatment, and quality documentation of LCA data. Italian National Agency for New Technologies (ENEA). ISBN 88-8286-110-4.

282. Weidema, B.P. (2006): The integration of economic and social aspects in life cycle impact assessment. International Journal of Life Cycle Assessment 11 (1): 89-96.

283. Weidema, B.P. (2008): Using the budget constraint to monetarise impact assessment results. Ecological Economics 68(6):1591-1598.

284. Weidema, B.P. (with contributions from Lindeijer, E.) (2001): Physical impacts of land use in product life cycle assessment. Subject report of the EURENVIRON-LCAGAPS sub-project on land use. IPL 033-01, Department of Manufacturing Engineering and Management, Technical University of Denmark, Lyngby, Denmark.

285. Weinstein, M.C. and Stason, W.B. (1977): Foundations of cost-effectiveness analysis for health and medical practices. The New England Journal of Medicine 296: 716-721.

286. Wenzel, H. (1998): Application Dependency of LCA Methodology: Key Variables and Their Mode of Influencing the Method. International Journal of Life Cycle Assessment 3: 281-288.

287. WHO (1987): Ozone. In: Air Quality Guidelines for Europe. WHO Regional Publications, European Series No 23, Copenhagen. pp. 315-326.

288. WHO (1989): Indoor air quality: organic pollutants. EURO Reports and Studies 111, WHO Regional Office for Europe, Copenhagen.

289. WHO (2002): Global Burden of Disease statistics 2002 (http://www.who.int/healthinfo/bodestimates/en/index.html).

290. Wolff, S. (2000): Evaluation of fine particle exposures, health risks, and control options. Doctoral thesis. Department of Environmental Health, Harvard School of Public Health, Boston, MA, USA.

291. World Health Organization (2004): Health aspects of air pollution – answers to follow-up questions from CAFE. Report on a WHO working group meeting, 15-16 January 2004, Bonn, Germany.

292. World Meteorological Organization (1999): Scientific Assessment of Ozone Depletion: 1998. Global Ozone Research and Monitoring Project – Report No 44. ISBN 92-807-1722-7.

293. World Meteorological Organization (2003): Scientific Assessment of Ozone Depletion: Global Ozone Research and Monitoring Project – Report No 47.

294. Zamagni, A., Buttol, P., Porta, P.L., Buonamici, R., Masoni, P., Guinee, J., Heijungs, R., Ekvall, T., Bersani, R., Bienkowska, A., Pretato, U. (2008): Critical review of the current research needs and limitations related to ISO-LCA practice. CALCAS project report D7. Italian National Agency for New Technologies (ENEA). ISBN 88-8286-166-X.

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**Abstract**

Life Cycle Thinking (LCT) and Life Cycle Assessment (LCA) are the scientific approaches behind modern environmental policies and industry decision support related to sustainable consumption and production and a resource-efficient society.

In the Communication on Integrated Product Policy (IPP), the European Commission committed itself to produce a handbook on best practice in LCA. The Sustainable Consumption and Production and Sustainable Industrial Policy Action Plan (SCP/SIP) confirmed that "...consistent and reliable data and methods are required to assess the overall environmental performance of products...". Finally, yet importantly, the 2011 Communication on a resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy takes a life cycle approach to reduce the environmental impacts caused by resource use, restating the necessity to work with a consistent analytical approach. Responding to these needs, the International Reference Life Cycle Data System (ILCD) Handbook provides governments and industry with a basis for assuring quality and consistency of life cycle data, methods and assessments.

This JRC Reference Report (JRC RR) is a non-technical umbrella document for the guidance documents of the ILCD Handbook. This JRC RR provides overview information on the Handbook components and how they are interrelated, and lists the main supporting documents and tools. It also suggests formulations for effectively referring to the ILCD Handbook and its related components in the policy and market context. It therefore addresses policy-makers, policy and scientific officers in public authorities, upper and middle management, lower management and desk officers in industry and other stakeholders who are responsible for the development, implementation and monitoring of life cycle-related policies and strategies with an environmental component, or who commission related service contracts and research and development projects.

The principle target audience of the technical guidance documents of the ILCD Handbook are LCA practitioners and technical experts in the public and private sector dealing with environmental decision support related to products, resources and waste management.

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