Christofer Skaar

Accountability in the Value Chain: Product Declarations as a Tool for Measuring, Managing and Communicating CSR Performance

Thesis for the degree of Philosophiae Doctor

Trondheim, January 2013

Norwegian University of Science and Technology
Faculty of Social Sciences and Technology Management
Department of Industrial Economics and
Technology Management

NTNU – Trondheim
Norwegian University of
Science and Technology

NTNU
Norwegian University of Science and Technology

Thesis for the degree of Philosophiae Doctor

Faculty of Social Sciences and Technology Management
Department of Industrial Economics and Technology Management

ISBN 978-82-471-4107-6 (printed ver.)
ISBN 978-82-471-4108-3 (electronic ver.)
ISSN 1503-8181

Doctoral theses at NTNU, 2013:9

Printed by NTNU-trykk

Every theory has its holes
When real life steps in

J. Biafra

Abstract

Corporate Social Responsibility (CSR) is a concept applied to business organisations that choose to behave beyond the legal requirements for their impacts on society and the environment. A central activity of CSR is to communicate with society, i.e. through credible reporting the organisation makes itself accountable to the public. The scope of accountability is not limited to single organisations or single aspects. Social and environmental aspects in the whole value chain must be addressed.

The purpose of this research is to develop and present a framework for managing and communicating on CSR aspects in the value chain; appropriately called the framework for Management and Communication of Environmental and Social aspects (MCES). The theoretical background of the research is systems thinking, CSR and Industrial Ecology (IE). The framework integrates product reporting with a management system based on the principle of continual improvement. Economic aspects are not included.

A literature review of management, certification and reporting approaches identified two gaps in current practices. The first is that there are no globally recognised reporting approaches that deal with both the processes and the organisations that together constitute the value chain. The second is that there are no reporting approaches that deal with both social and environmental aspects in the value chain. The literature review suggests that there is a need for such an integrated approach. This is the first contribution of the research.

An exploratory case study was conducted in the Norwegian furniture industry in the period between 2005 and 2010. The case study was divided into four phases. Practical results include the DATSUPI software and a verified LCA database, which can be used together for documenting environmental and social performance of products and for creating Environmental Product Declarations (EPDs). The assessment of social performance in the case study is limited to chemical use in the production phase and emissions from products in the use phase. From this comes the second contribution of the thesis, integrating product emissions in the use phase into a Life Cycle Assessment (LCA), which can in turn be included in a product declaration.

The third contribution of the research is the MCES framework, which integrates product reporting with a plan-do-check-act management system. The framework is based on product reporting as a central activity in a continual improvement perspective, where improvement can be for a product, for a reporting system, for an organisation or for a value chain. The framework relies on the use of performance indicators with the intention of including both environmental and social aspects. The results of the case study indicate that the main challenge when applying such a framework is that of finding indicators that can be allocated and aggregated throughout the value chain and remain meaningful. This supports the initial findings of the literature review. Future progress depends on a scientific consensus on indicators and aggregation methods, which means that in the near term transparency in reporting is critical for CSR.

Preface

This thesis is submitted to the Norwegian University of Science and Technology (NTNU) for partial fulfilment of the requirements for the degree of philosophiae doctor. The thesis consists of a summary of the research, six research publications and a Product Category Rules (PCR) document.

This doctoral work has been performed at the Department of Industrial Economics and Technology Management, NTNU, Trondheim, with Professor Annik Magerholm Fet as main supervisor and with Dr. Ing. Kjell Øren as co-supervisor.

The PhD has been performed as part of the project C(S)R in Global Value Chains: a Conceptual and Operational Approach, sponsored by the Norwegian Research Council (project number 171658). Partial funding has been provided by the Department of Industrial Economics and Technology Management that granted me a four month stipend for finalising the PhD, allowing me to finish what at times felt like a marathon, without having to share the fate of Pheidippides.

Acknowledgements

Writing this thesis would not have been possible without the help and support of my family, friends and colleagues. I would first like to thank Annik Magerholm Fet for her support and encouragement throughout the years we have worked together. Starting in 2004 I worked with Annik on several research projects related to eco-efficiency in Norwegian industries. These research projects provided a stepping stone for pursuing a PhD. Working with Annik has always given me the opportunity to be involved in exciting research projects that included numerous industry partners and research institutions and provided the opportunity for results to be developed, tested and used in real life cases. This has been a positive factor in my education as a researcher. I would also like to thank Kjell Øren for our discussions, which have been an inspiration to always think and rethink my research ideas and to strive towards research that is relevant beyond academia.

I would also like to thank the two other co-authors of the thesis publications, Ottar Michelsen and Rikke Jørgensen, for allowing my research to expand into disciplines that I could not have penetrated alone. I would furthermore like to thank the case companies and their representatives for their active participation, in particular Magnar Skjellum at Helland Møbler AS and Johannes Håskjold and Arve Ekornes at Ekornes ASA. I would also like to express my gratitude to the Norwegian EPD Foundation (EPD Norway), in particular Bjørn Sveen, Sverre Fossdal and Dagfinn Malnes, for their continuous efforts to advance the Norwegian EPD system through research and experience. Numerous students and researchers have been co-contributors in the research projects through the years, too many to thank individually. But one person, Børge Heggen Johansen, deserves a particular mention for his dedication to the work at hand and for his ability to always let his cheerful spirit influence those around him.

Furthermore, I would like to thank my colleagues at the Department's section for Health, Safety and Environment (HSE), in particular Dina Aspen, Alexander Dahlsrud and John Hermansen. I am especially grateful to Cecilia Haskins, with whom I have shared an office with for the past years. She has been a source of inspiration and a discussion partner who has always challenged me to explain and clarify my ways of thinking in systems. I would also like to thank her for helping me with the language in my thesis and for saving our office plants each time they were trying to call for help when I so often neglected them.

Finally I would like to thank my wife and daughter. Anni and Oda, without you I could never have finished this. Thank you for always supporting me and inspiring me, even though the road was longer and more winding than foreseen.

Table of contents

List of Figures

List of Tables

ABBREVIATIONS

CTU	Comparable toxic unit
CRM	Carcinogenic, reprotoxic and mutagenic
CSR	Corporate Social Responsibility
DALY	Disability Adjusted Life Years
DPSIR	Driving forces-Pressures-States-Impacts-Responses
DATSUPI	Data Assisted Tool for Sustainability Product Information
ECI	Environmental Condition Indicator
EF	Effect factor
EEA	European Environmental Agency
EMS	Environmental Management System
EMAS	EU Eco-Management and Audit Scheme
EPD	Environmental Product Declaration
FAD	Ministry of Government Administration, Reform and Church Affairs *(Fornyings-, administrasjons- og kirkedepartementet)*
FU	Functional unit
GEO-4	Global Environmental Outlook (report number 4)
GST	General Systems Theory
GRI	Global Reporting Initiative
IAQ	Indoor Air Quality
IPAT	Impact = population x affluence x technology
IR	Inhalation rate
IE	Industrial Ecology
IIGSS	International Institute for General System Studies
ISO	International Organization for Standardization
ILO	International Labour Organization
LCIA	Life Cycle Impact Assessment
LCM	Life Cycle Management
LCI	Life Cycle Inventory
LCC	Life Cycle Costing
LCA	Life Cycle Assessment
MD	Norwegian Ministry of the Environment *(Miljøverndepartementet)*
MSDS	Material Safety Data Sheet
MDG	Millennium Development Goals
MPI	Management Performance Indicator
MCDA	Multi-Criteria Decision Analysis
MCES	Framework for Management and Communication of Environmental and Social aspects
NTNU	Norwegian University of Science and Technology
NFR	Research Council of Norway *(Forskningsrådet)*
OHS	Occupational Health and Safety
OPI	Operational Performance Indicator
PDCA	Plan Do Check Act
PCR	Product Category Rules
QALY	Quality Adjusted Life Years
REACH	EU Regulation on Registration, Evaluation, Authorisation and Restriction of Chemical substances
S-LCA	Social Life Cycle Assessment
SME	Small and medium sized enterprises
SETAC	The Society of Environmental Toxicology and Chemistry
SD	Sustainable Development
SE	Systems Engineering
UNCED	United Nations Conference on Environment and Development
UNWCED	United Nations World Commission on Environment and Development
UNEP	United Nations Environment Programme
UN	United Nations
WBCSD	World Business Council for Sustainable Development
WCED	World Commission on Environment and Development
WHO	World Health Organization
XML	Extensible Markup Language

1 Introduction

1.1 Background

Corporate Social Responsibility (CSR) is a concept applied to business organisations that choose to take responsibility beyond legal requirements for their impacts on society and the environment (European Commission, 2011). Although there is no singular definition of CSR, it is often linked to sustainable development, human rights and ethical behaviour. A key characteristic of CSR is the explicit focus on stakeholders and voluntariness, in addition to the economic, social and environmental aspects of sustainability (Dahlsrud, 2006).

Reasons for an organisation to engage in CSR can be found both internally in and externally of the organisation, as drivers and pressures and motivated by value or values. Whatever the rationale, the result is the introduction of new business aspects that should be managed systematically by the organisation. Following the managerial creed that 'what gets measured gets done' and responding to demands from external stakeholders to be transparent and act responsibly, an organisation can choose to communicate on CSR aspects and strive towards accountability. Accountability is a key element of being a responsible organisation (Zadek, 2007). Being accountable goes beyond reporting, it means that information that is communicated must be verified in a credible manner (Dando and Swift, 2003) and that the results are made public (Pintér et al., 2012; Sethi and Emelianova, 2006).

The background for this research is a series of research projects on environmental accountability in the Norwegian furniture industry, originating from the Norwegian University of Science and Technology (NTNU). In the 1990s the initial focus was on annual environmental reporting, evolving over time towards a broader level of accountability at the product level in the 2000s. This coincided with a growing national focus on accountability and CSR. The Research Council of Norway (NFR) called for research on tools and methods for accountability; tools and methods that also could be applied by small and medium sized enterprises (SME) (Norges forskningsråd, 2004). Three central research themes relating to accountability were identified by the NFR: reporting systems, auditing and verification, and sanctioning mechanisms.

Influenced by this growing focus on CSR, two research areas were of particular interest. The first was how furniture companies (which are mainly SME) can systematically engage in environmental accountability in the value chain and the second was how product level accountability could be expanded to address social aspects. The research builds on previous research on extended supply chains (Michelsen, 2006), accountability (Lamberton, 2005) and systems engineering (Asbjørnsen, 1992; Fet, 2002; Haskins, 2008; Schau, 2012).

The purpose of a value chain is typically to provide a product. In this research there are three different systems of interest when discussing CSR in value chains. The first system is the *corporation*, covering the activities of a single entity. This can be a corporation, a production site or a business unit within a corporation. The second system is the *extended supply chain*.

This is the traditional supply chain, defined as a "network of connected and interdependent organisations mutually and co-operatively working together to control, manage and improve the flow of materials and information from suppliers to end users" (Aitkens in Christopher, 2005: 6), extended to include the use and end of life stages. The focus here is on the organisations in the value chain. The third system is the *product life cycle*. Here the system consists of the individual production processes in the value chain. The term value chain here refers collectively to the two last systems; the extended supply chain and the product life cycle.

An organisation engaging in CSR should have management systems in place to deal with its environmental and social aspects systematically, just as they do for financial and quality aspects. A robust management system will address aspects both within the organisation itself and within its value chain (Finkbeiner et al., 1999). This is reflected in the field of environmental management, which has over the last decades been broadened to include environmental aspects not only in the organisation, but also in the value chain (e.g. the focus on products in ISO 14001 (ISO, 2004b)). Furthermore, it has been argued that the system boundaries of environmental and social assessments should be identical in order to avoid problem shifting (Weidema, 2005). Therefore the environmental management system presents itself as a potential starting point for integrated management of environmental and social aspects in the value chain.

1.2 Research questions

The main goal of this research is to contribute to increased understanding of CSR accountability in the value chain, through analysing how an organisation can quantify, manage and communicate CSR performance at the product level. Three research questions have been formulated towards this goal:

1) What is the current practice for firms to measure and communicate product performance?
2) What is the influence of CSR on product declarations?
3) How can CSR performance be measured, managed and communicated for products?

The research questions are of an exploratory nature to allow the direction of the research to be influenced by findings and opportunities along the way. The findings are synthesised into the proposed framework for managing and communicating on CSR aspects in the value chain.

The scope of this research is not be limited to single organisations or single issues, rather it encompasses organisations and processes in the whole value chain, from cradle to grave and from cradle to cradle; covering economic, social and environmental aspects (Porter and Kramer, 2007). The complexity of this scope calls for a systems approach (Azapagic, 2003; Meadows and Club of Rome, 1972), where a system is "a set of interrelated components working together toward a common objective" (Kossiakoff et al., 2011: 23).

1.3 Research design

The research design is shown in Figure 1. The outermost box is the context of the research, which is sustainability and sustainable development (box 1). Sustainability is here understood both as the idea of sustainability in an ecological sense as well as the vision that a sustainable society can be achieved by developing principles for sustainability that are inspired by nature (Korhonen, 2004). Sustainable development is seen as the motivation for CSR (European Commission, 2011). Within this context three concepts have been chosen (box 2), selected to provide multiple perspectives on sustainability: systems thinking, industrial ecology and CSR. The concepts are both influenced by sustainability and attempting to address sustainable development, as the arrows between the boxes indicate. Together they provide a canvas for the research that has been done. The analytical framework (box 3) has been developed drawing on elements from the three concepts.

The tools (box 4, within the analytical framework) are used to address the three research questions (Q1-Q3 within box 3), with systems engineering being the organising principle. The final selection of tools is the result of iterating between literature review and case study, which have been the two principle research methods. The results are presented in six publications emanating from the analytical framework, and included in the appendices. Four of the publications (numbered 2, 3, 5 and 6) are based on case studies in the Norwegian furniture manufacturing industry. The main outcome of the thesis (box 5) is a framework for management and communication of CSR product performance. This framework is based on an integrated use of tools and is a contribution to the scientific discourses at the concept levels, in particular to industrial ecology and CSR.

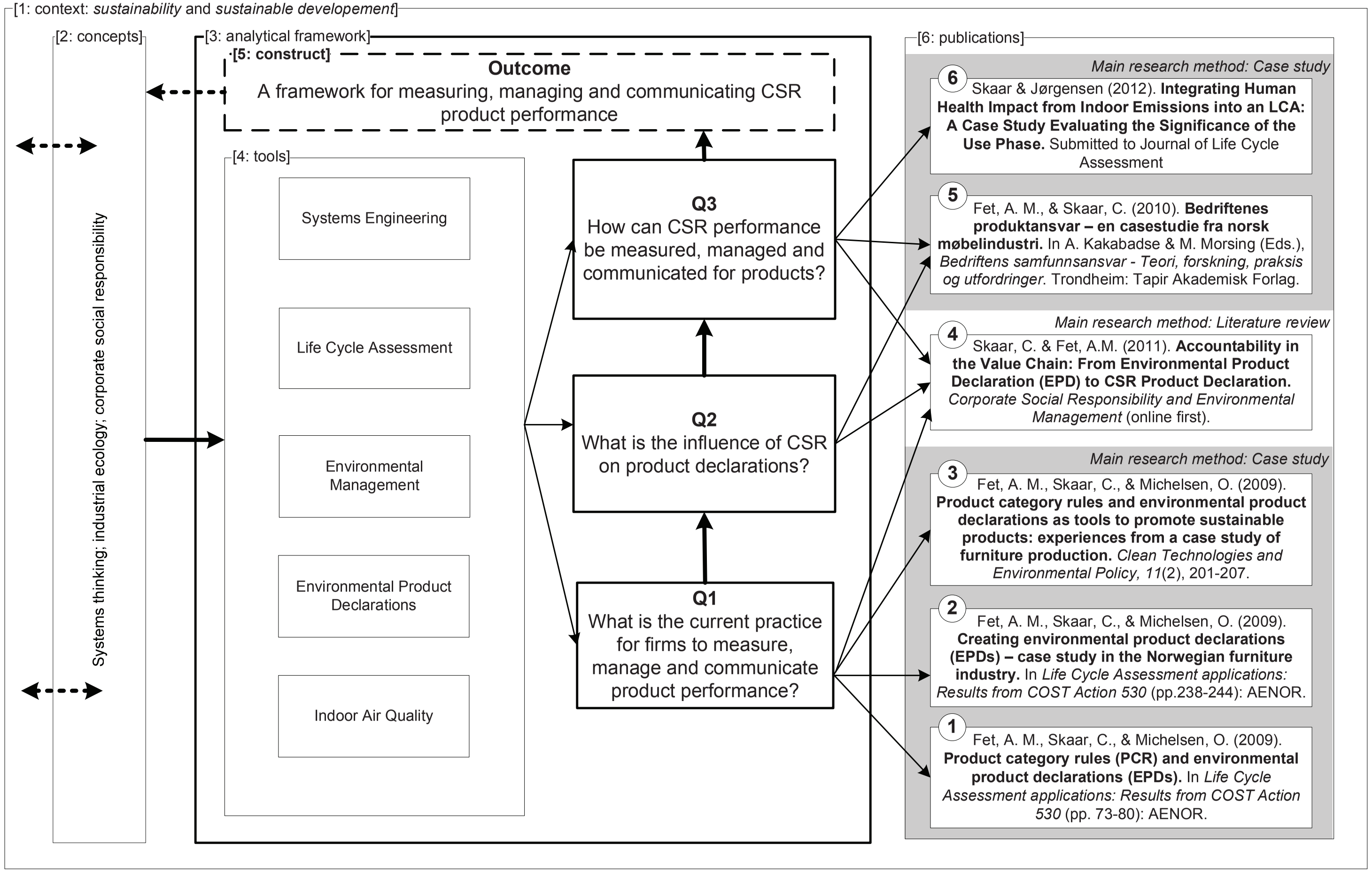


Figure 1: Research design

1.4 Scientific contributions

The primary scientific contributions of this research are related to quantifying, managing and communicating CSR performance at the product level:

- Identify gaps in current accountability approaches (Paper 4)
- Developing a method to integrate the impact of emissions in the use phase into a life cycle assessment (LCA) (Paper 6)
- Create a framework for measure, manage and communicate on CSR in the value chain, based on principles from environmental management (Chapter 6)

During the course of the research a number of secondary scientific contributions have been made that were not directly related to the initial research questions. These secondary contributions are:

- Contributing to the development of a modular software: Data Assisted Tool for Sustainability Product Information (DATSUPI) (2009b; 2009) and sections 5.3 and 6.3
- Publication of results from a series of research projects in the Norwegian furniture industry, funded by NFR and with Professor Annik Magerholm Fet as project leader (Fet et al., 2009a; Fet and Skaar, 2010; Fet et al., 2009c, 2009d). Year initiated and project titles are:
    - 1998: Produktivitet 2005 - Industriell økologi *(Productivity 2005 – Industrial Ecology)*
    - 2005: Modulbasert produktutviklings- og kommunikasjonsverktøy for møbelproduksjon *(Module based product development and communcation tool for furniture production)*
    - 2006: C(S)R in global value chains, a conceptual and operational approach
    - 2007: Dataassistert verktøy for bærekraftig produktinformasjon *(Data assisted tool for sustainability product information, DATSUPI)*
- Development of PCR documents for four product categories in the Norwegian EPD system: 1) seating, 2) beds and mattresses, 3) tables and 4) upholstery textiles (EPD Norway, 2005, 2006, 2008, 2009a)

The scientific outcome of the thesis is six publications (three journal articles and three book chapters), as shown in box 6 in Figure 1 and briefly presented below, in Table 1. Furthermore, as mentioned above, three Product Category Rules (PCR) documents have been created for furniture products and one PCR document has been created for textiles. The four PCR documents provide guidance and rules for creating Environmental Product Declarations (EPDs) that are in accordance with the ISO 14025 standard. The PCR for seating is included in Appendix 7 as an example.

1.5 Thesis structure

The thesis consists of 8 chapters, followed by references and appendices. Chapter 1 introduces the background of the research, the research questions and the research design. Chapter 2 presents the context of the research, including aspects of sustainability related to sustainable development, measuring sustainability and value chains. Chapter 3 introduces the theoretical foundations, which are systems thinking, industrial ecology and corporate social responsibility.

Chapter 4 provides an overview of the methods and tools that have been used in the case studies.

The case study and research results are subsequently presented in Chapter 5, followed by the presentation of a framework for managing and communicating on environmental and social aspects in Chapter 6. This framework is the construct, as shown in the research design in Figure 1. Chapter 7 discusses the research methods and tools, and the research outcomes in relation to the research questions and limitations of the research. Finally, Chapter 8 presents the main conclusions, as well as ideas for future research.

The main findings are presented in the research publications listed in Figure 1. A listing of the papers with their abstract is presented in Table 1, and the full text can be found in the respective appendices (Paper 1 is located in Appendix 1, etc.).

Table 1: Publications

#	Reference and summary
1	Fet, A. M., Skaar, C., & Michelsen, O. (2009). **Product category rules (PCR) and environmental product declarations (EPDs)**. In Life Cycle Assessment applications: Results from COST Action 530 (pp. 73-80): AENOR.
	This paper presents the requirements of the ISO 14025 standard for environmental declarations for Product Category Rules (PCR), Environmental Product Declarations (EPD) and EPD programmes. The requirements relate to both the content of the EPD and PCR, as well as the process of developing them. The intention of the EPD is to provide objective and quantified environmental information. It must be developed following requirements defined in the PCR, and the PCR must be developed through an EPD programme. The EPD programme also has the responsibility for establishing verification procedures for EPDs. Furthermore, an overview is provided of the ISO 14025 in relation to other ISO standards concerning product related environmental labels and declarations.
2	Fet, A. M., Michelsen, O., & Skaar, C. (2009). **Creating environmental product declarations (EPDs) – case study in the Norwegian furniture industry.** In *Life Cycle Assessment applications: Results from COST Action 530* (pp.238-244): AENOR.
	Manufacturing companies are exposed to an increasing demand for declaration of the environmental performance of their products. In particular, small and medium sized enterprises (SMEs) have large challenges in meeting these requirements due to lack of resources and knowledge on environmental issues. To assist the companies in this process, a database on furniture production in Norway is under way. This helps manufacturers to assess the environmental performance of the different materials in their products. This information can be used in environmental product declarations (EPDs). The information about environmental impacts together with cost assessments can also be used to assess the eco-efficiency of the products.
3	Fet, A. M., Skaar, C., & Michelsen, O. (2009). **Product category rules and environmental product declarations as tools to promote sustainable products: experiences from a case study of furniture production.** *Clean Technologies and Environmental Policy, 11*(2), 201-207.
	New requirements and regulations have increased the pressure on companies to provide information on their products. This is challenging for small- and medium-sized enterprises (SMEs) since they lack both expertise and resources. In this paper, the possibilities to develop environmental product declarations (EPDs) for products with use of data-assistant tools are explored. A case study of furniture production in Norway is used to exemplify this. A database with specific environmental data for materials used in furniture has been developed. The database is used to conduct the life cycle assessment (LCA) for selected products and is the backbone of a data assistance tool used to design and present the EPDs. Five key performance indicators are selected. The database and these KPIs ensures standardised assessments of products that enables both comparison of existing products as well as assessment of environmental performance of redesigned products and potential new products. This paper shows how this enables the SMEs to both provide environmental performance information to stakeholders as well as enables them to identify possible improvements with limited resources and competence on environmental performance and LCAs.

#	Reference and s**ummary**
4	Skaar, C. & Fet, A.M. (2011). **Accountability in the Value Chain: From Environmental Product Declaration (EPD) to CSR Product Declaration.** Corporate Social Responsibility and Environmental Management (online first). Reporting on corporate social responsibility (CSR) performance to external stakeholders is a key element of corporate and value chain accountability. This paper identifies gaps in existing value chain reporting practices and examines options for how a CSR product declaration can be developed to address these gaps. The characteristics of six state-of-the-art accountability management, reporting, and certification approaches are identified and the pairwise correlations are assessed statistically. Findings show that the overall correlation is low; there is no low-hanging fruit for combining existing elements. Missing allocation and aggregation methods are a particular challenge, especially concerning social aspects in the value chain. Three options for a CSR product declaration based on the Environmental Product Declaration (EPD) are presented. Building on the strength of the EPD (transparency, quantification, and verification), a scientific consensus building approach is recommended. Indicator development becomes a balancing act between satisfying internal management requirements and keeping connected with the scientific development.
5	Fet, A. M., & Skaar, C. (2010). **Bedriftenes produktansvar – en casestudie fra norsk møbelindustri.** In A. Kakabadse & M. Morsing (Eds.), *Bedriftens samfunnsansvar - Teori, forskning, praksis og utfordringer*. Trondheim: Tapir Akademisk Forlag. *This paper is a book chapter in Norwegian. Below is a translated summary of the contents.* The first part of this paper concerns the regulatory environment that companies are facing in Norway. It provides an overview of the two most important laws, the accounting act and the environmental information act, as well as a select number of documents that are not legally binding (i.e. soft law) such as the white paper on corporate social responsibility and ISO standards. The second half presents a case study of DATSUPI in the Norwegian furniture industry, exemplifying how EPD generation can be streamlined and how occupational health aspects can be integrated in EPDs. The focus of the occupational health aspects is on the use phase of furniture. The paper summarises the main findings and outlines the main challenges for mainstreaming the use of software such as DATSUPI.
6	Skaar, C., & Jørgensen, R. B. (2012). **Integrating Human Health Impact from Indoor Emissions into an LCA: A Case Study Evaluating the Significance of the Use Phase**. First version submitted to *International Journal of Life Cycle Assessment* in January 2012, revised version submitted in May 2012. Indoor emissions of toxic substances from products can have a negative effect on human health. These effects are typically not considered in a Life Cycle Assessment (LCA), potentially underestimating the importance of the use phase. In this study a model is presented that integrates indoor emissions into LCA by nesting an indoor compartment in the USEtox model. Emissions over time (including best case and worst case scenarios) are modelled by using existing emission models and experimental data. A long-term time perspective (70 years) is selected, as emissions from a product may persist over time. Testing the model on a case study of a piece of furniture shows that the use phase is more significant than production and disposal combined. Furthermore, under certain circumstances emissions from a single product may lead to exposure above recommended limit values. Intake fraction (dependent on inhalation rate, exposure time and ventilation characteristics) is the most significant factor, with a factor of more than 700 between best and worst case. Recommended actions to reduce exposure are limiting early exposure (> 14 % of emissions may occur in the first month and > 50 % in the first year) and replacing furniture less frequently.

2 Research context

2.1 Sustainability and sustainable development

This research has been undertaken in the context of sustainability, with emphasis on the environmental dimension. Sustainability is an ideal state where society and nature are able to be sustained over time without overstepping the limits of the Earth's regenerative capacity (Wackernagel et al., 2002) and where the dignity and authenticity of human beings are secured (Ehrenfeld, 2005).

In order to make sustainability operational, it is necessary to know what it is that should be sustained. In an environmental perspective this can be defined as "ecological services and natural resources" (Wackernagel et al., 2002: 9266). It is a challenge that "['t]rue sustainbility', i.e. where a certain system sustains itself over long term, in fact, forever, can only be considered by looking backwards" (Korhonen, 2003: 36). This leaves us with three options: carry on as usual, identifying unsustainable practices (what not to do) and identifying less unsustainable practices (a potential path to sustainability). One proposed such path to sustainability is sustainable development.

In 1987 the report *Our Common Future* (also called *The Brundtland Report*) was published by the World Commission on Environment and Development (WCED) (1987). The report was an outcome of the WCED, linking environmental and social sustainability to each other and to economic stability using the term "sustainable development" (SD). Sustainable development was defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987). The shift from sustainability to sustainable development has been welcomed for its explicit focus on the conditions of the poorest, but also criticised for over sight of the initial goals over time (Victor, 2006). The United Nations Environment Programme (UNEP) noted in 2007 in its Global Environment Outlook GEO-4 that "real progress towards sustainable development has been slow" (UNEP, 2007: 11). The progress and the road ahead were topics for the upcoming United Nations Conference on Sustainable Development (Rio+20) held in 2012 (United Nations Conference on Sustainable Development, 2012).

Sustainable development "is a process with moving targets and goals based on the general long-term goals" (Baumgartner, 2011: 785). Targets can move either from increased knowledge on processes and interlinkages, or because there has been a contextual shift (Missimer et al., ; Mitchell et al., 2004). A general challenge is that any development may be offset by unintended rebound effects that outweigh improvements that are made (Hertwich, 2005; Korhonen, 2003, 2004).

In *Our Common Future* it is stated that "in the final analysis, sustainable development must rest on political will" (World Commission on Environment and Development, 1987). Political will is central in sustainable development (Glavic and Lukman, 2007), but not in isolation. The World Business Council for Sustainable Development (WBCSD) has stated that "building effective solutions to complex sustainable development challenges requires the active participation and collaboration of government, business, civil society and other key stakeholders" (WBCSD, 2010: 21). In *Agenda 21* – an initiative of the United Nations Conference on Environment and Development (UNCED) – a recommended action is to "strengthen partnerships to implement the principles and criteria for sustainable development" (United Nations Conference on Environment and Development, 1992). In this context, partnerships can be both within and between industry, governments and non-governmental organizations (NGOs).

2.2 Measuring sustainability

The starting point for measuring sustainability is to measure unsustainability (i.e. social and environmental impact). The IPAT equation (impact = population x affluence x technology) was formulated by Ehrlich and Holdren coming out of discussions with Commoner in the 1970s (Steinberger and Krausmann, 2011). First proposed as a measure of environmental impact, the definition of the factors and the interlinkages between the factors were – and still are – a matter of debate (Chertow, 2000). As a concept the equation illustrates the fact that there are linkages between environmental, social and economic aspects. It should be noted that the intention is not to remove environmental impact, but to keep the impact within the carrying capacity of the Earth's eco-systems. The use of the equation has evolved into not only identifying the unsustainable, but as a way to find a path to sustainability (Chertow, 2000). A distinction must here be made between *measuring* unsustainability and *assessing* sustainability (Ehrenfeld, 2005). This notion is supported by Lamberton, stating that "[s]ustainability being a multi dimensional concept is not directly measurable and requires a set of indicators to enable performance toward its multiple objectives to be assessed" (Lamberton, 2005: 13).

A number of approaches have been proposed to measure progress towards sustainability, with varying purpose, object, scope and methodological approach (Pintér et al., 2005; Skaar and Fet, 2011). Any measurement must be related to a reference frame in order to make sense, for example the state of the world (e.g. the GEO-4 (UNEP, 2007) or the Millennium Development Goals (MDG) (UN, 2011)), a set of general sustainability principles (Ny et al., 2006; Wang and Graedel, 2006) or models of impact pathways (Parent et al., 2010). It has been shown that "any attempts to account for SD performance is likely to be incomplete, putative and experimental and require considerable patience on behalf of researchers" (Bebbington, 2009: 189) and that the way forward could be to focus on "methodological pluralism coupled with stakeholder participation" (Gasparatos et al., 2009: 192). This is also the case for any business organisation that attempts to measure its impact on sustainability (WBCSD, 2008), which should be considered both in a geographical and product system context (Azapagic and Perdan, 2000; Korhonen, 2002; Vachon and Mao, 2008). A challenge for any measurement approach is that the act of measuring could become more visible than behaviour and actual performance (Moneva et al., 2006).

2.3 Products and the value chains

The terms value chain, supply chain, life cycle and variants of these (e.g. extended supply chain, commodity chain, supply network, value network) have multiple understandings, are interrelated and often overlapping from one definition to another (Faße et al., 2009; Kaplinsky and Morris, 2000; Seuring, 2004). The value chain is here defined as the combination of 1) the extended supply chain (i.e. the organisations in the value chain) and 2) the product life cycle (the processes in the value chain). The purpose of a value chain is to provide a product, where product is understood to also include services.

A value chain will typically have a number of internal and external stakeholders (Stevels, 2007). Although termed a chain, a value chain is used to describe complex, interconnected systems of organisations and processes that interact with the natural and social environment. To link value chains to sustainability it is necessary to move the focus from reporting practices to accountability practices that can create behavioural change (Schaltegger and Burritt, 2010).

A value chain can be described by mapping stakeholders, processes and information and material flows between processes and organisations. Processes can be measured and modelled through the use of performance indicators, where the performance indicators can be based on flows between processes in the value chain and between the value chain and its surroundings (manmade systems or nature) or attributes of the process. Challenges include identification of appropriate and meaningful performance indicators (Schaltegger and Burritt), aggregation of performance indicators, and weighting of performance indicators (Skaar, 2010). The performance indicators chosen do not exist in a vacuum, but must be interpreted and understood in relation to their surroundings.

An analytical variant of value chain analysis is Life Cycle Assessment (LCA) (Balkau and Sonnemann, 2010), which is concerned with material flows related to the value chain. LCA is here defined as a tool, as LCA is used extensively in the case study.

3 Theoretical foundations

Systems thinking, industrial ecology and corporate social responsibility (CSR) are the three overarching theoretical concepts applied in this research. Within each concept a number of analytical and procedural tools are found. Systems thinking is furthermore used as an organising principle in the research, in particular through drawing on systems engineering (Fet, 1997) to define, describe and analyse the system of interest. CSR is the rationale for why an organisation should manage its social and environmental aspects, in addition to the economic. Industrial ecology provides principles for modelling the system and assessing its environmental impact. These concepts are used in combination to shed light on the three research questions.

3.1 Systems thinking

Although the history of thinking in systems has long historical roots (Lin, 2007; Mandel, 1997), the origin of modern systems thinking is often attributed to the General Systems Theory (GST) (Haskins, 2008), as introduced by Bertalanffy (1968). Systems thinking is central in a multitude of other more or less related concepts and methods, as shown in an overview by the International Institute for General System Studies (IIGSS, 2001).

A system is a combination of components that together form a whole that is providing a function; it is “a set of interrelated components working together toward some common objective” (Blanchard and Fabrycky, 1990: 2). The system is defined by the interactions within the system and between the system and its surroundings, where interactions can be physical or non-physical. Systems can be viewed as a hierarchy, consisting of system, sub-system(s) and components. The definitions are relative; a system can itself be seen as a sub-system at a higher level in the hierarchy, as in systems of systems. Building on Asbjørnsen (1992), Fet (2002) identifies five disciplines that are required in systems thinking. These are technical science, financial science, information science, social science and natural science.

From systems thinking numerous theoretical and methodological approaches have grown, for example system dynamics (as used by Meadows et al. (1972) in *The Limits to Growth*) and systems engineering (SE) (see Section 4.2.1). Systems thinking is fundamental in all the theoretical concepts presented here, but it is most explicit in industrial ecology (e.g. in Fet (2002))

3.2 Industrial Ecology

Industrial Ecology (IE) has been defined by Frosch (1992: 800) as “the network of all industrial processes as they may interact with each other and live off each other, not just in the economic sense but also in the sense of direct use of each other’s material and energy wastes and products”. The industrial ecology concept is built on systems thinking, using biological ecology and eco-systems as metaphors for how industrial systems should be designed (Duchin et al., 2008). The main principle of industrial ecology is to optimise the use of resources, energy and capital (Graedel and Allenby, 1995) in order to increase productivity and eliminate harm. Strategies within industrial ecology in this context are closing material loops (increased resource use effectiveness, increased recycling/reuse, dematerialisation) (Wang and Graedel, 2006), substituting hazardous materials with less hazardous ones (Wang and Graedel, 2006) and producing less toxic by-products (Duchin et al., 2008) (reducing harm).

Industrial ecology has been linked to sustainability through a variant of the IPAT equation (Chertow, 2000; Wang and Graedel, 2006), presented by Graedel and Allenby as the *master equation* (Graedel and Allenby, 1995: 5):

$$Environmental\ impact = population \times \frac{GDP}{person} \times \frac{environmental\ impact}{unit\ of\ per\ capita\ GDP} \qquad [1]$$

The unit of analysis in industrial ecology is flexible, and can be geographical (Kissinger and Rees, 2009) or product-based (Korhonen, 2002). In the product-based approach it should not be the single physical product that is of interest, but rather the function it provides (Bauman and Tillman, 2004). Furthermore, the analysis can focus on production or consumption (Lifset, 2008) and it can be descriptive or change-oriented (Finnveden et al., 2009). Several methods have been developed that use industrial ecology to inform business strategy (Finster et al., 2002; Korhonen, 2004; Möller and Schaltegger, 2005).

Initially having mainly an environmental focus, the scope of industrial ecology has broadened to include economic aspects (e.g. combined use of Life Cycle Assessment and Life Cycle Costing (LCC) (Guinee et al., 2006; Norris, 2001)) and social aspects (Andrews et al., 2009; Hellweg et al., 2009; Norris, 2006; Pettersen and Hertwich, 2008).

3.3 Corporate Social Responsibility

Corporate Social Responsibility (CSR) as a concept does not have a singular definition, and is highly dependent on the perspective of the viewer. Dahlsrud (2006) analysed 37 different definitions of CSR, and identified five aspects of CSR as stakeholder, environment, social, economic and voluntariness. The stakeholder aspect should not be limited to one-way communication from an enterprise, but be dialogue based (Morsing and Schultz, 2006). CSR is here defined in accordance with the European Commission's definition of CSR as "the responsibility of enterprises for their impacts on society" (European Commission, 2011: 6), addressing the five aspects of CSR as identified by Dahlsrud. The scope of CSR is here considered to extend beyond the single organisation to the entire value chain. The relationship between CSR and sustainable development is that both concepts focus on social, environmental and economical aspects. CSR can be considered as the corporate contribution to sustainable development (Blindheim and Langhelle, 2010). In *ISO 26000 Guidance on social responsibility*, an ISO guidance standard, the content of social responsibility is defined around seven core subjects: organisational governance, human rights, labour practices, the environment, fair operating practices, consumer issues, and community involvement and development (ISO, 2010).

Garriga and Melé (2004) classifies CSR theories in four groups, based on four perceptions of the nature between business and society. The four groups are 1) instrumental theories: CSR as a means to maximise profit; 2) political theories: corporations have power in the society, and should use it responsibly; 3) integrative theories: corporations should integrate social demands in their operations (thereby gaining legitimacy); 4) ethical theories: CSR in light of universal rights and sustainable development. CSR, as defined in this thesis, falls into the fourth group.

The legitimacy of any variant of CSR that is not purely instrumental has been challenged for requiring management to go beyond the moral and legal responsibility of corporations (Friedman, 1970). Vogel (2005) stated that CSR currently is a niche market that makes sense for some companies in some circumstances. Furthermore Vogel states that CSR should not only be about going beyond standards, but also about raising the standards.

Following the assumption that you can't manage what you're not measuring (Foran et al., 2005), it is clear that in order to improve CSR performance in value chains it is necessary to provide decision makers with pertinent information. In other words, CSR performance indicators are needed. Such indicators (measurements) can be qualitative or quantitative. Information can be presented separately for each aspect, or expressed using integrated indicators that cover two or three aspects. Eco-efficiency indicators are examples of integrated indicators that take into account economic and environmental aspects (Kicherer et al., 2007), a concept that has evolved into socio-eco-efficiency (Schmidt et al., 2004).

As mentioned in the introduction, taking responsibility implies making oneself accountable. Accountability concerns both transparency, credibility and reporting (Kolk, 2008) (O'Connor and Spangenberg, 2008). Being accountable to stakeholders on environmental and social aspects is a challenge for an organisation, as there will be moving targets (stakeholders' shifting perception of what matters) (Zadek in Welford and Starkey, 2001). This requires a process of continuous accountability.

A challenge of the CSR viewpoint in general is that "by asking companies to take voluntary responsibilities beyond their business, we actually legitimize their increased power to decide and shape societal matters" (Halme et al., 2009: 6). This taps into an ongoing debate on the balance between corporations and the political system (i.e. private versus public), with positive (Hawken et al., 1999; Porritt, 2005; Prahalad, 2005) and negative viewpoints on business contribution to sustainable development (Bakan, 2004; Klein, 2000; Korten, 1995).

4 Methods and tools

The research design presented in Figure 1 shows an overview of the research methods and tools that have been used. The research design is multi-disciplinary, with literature review and case study methodology as overarching research methods. Literature review has been selected to gain insight into the research questions and to provide an overview of the state of the art of value chain accountability (see Paper 4)(Skaar and Fet, 2011, see Appendix 4 for full text). Case study methodology has been selected to analyse and provide empirical data on CSR accountability in the value chain. An iterative relationship exists between the literature review and the case study. This approach has been selected in reflection of the exploratory nature of the research questions and the nature of the research object being a series of research projects.

Within the case study a number of tools have been used to systematically analyse and account for a system's performance in a sustainability and CSR context. These tools are introduced in the following sections. It is possible to distinguish between procedural tools and analytical tools, where procedural tools are intended to provide guidelines on how to proceed in order to reach a decision and analytical tools are intended to provide qualitative or quantitative information that can be used to inform the procedural tools (Wrisberg, 2002). Systems Engineering (SE) and environmental management are here considered procedural tools, and Life Cycle Assessment (LCA), Indoor Air Quality (IAQ) and Environmental Product Declarations (EPD) are considered analytical tools. IAQ is a tool from the broader field of Occupational Health and Safety (OHS). Indicators are relevant in all tools, and a typology of indicators is therefore presented in Section 4.3. The integration of the tools into a framework for supply of CSR information is presented in Section 4.2.

All methods and tools are included in Figure 1. However, what is not shown in this figure is that the procedural tool of Systems Engineering (SE) is used at two levels. First it is used as a tool to organise the integration of all methods and tools that are applied in the analytical framework. Second, it is used as a tool within the case study to identify needs and requirements and develop solutions that meet these needs and requirements.

4.1 Research methods

4.1.1 Case study research

Selecting a research strategy depends on the research question. Case studies are often used for 'how' and 'why' questions, and according to Yin (2003) there are three main types of case studies: explanatory, exploratory and descriptive. Yin defines case study as an empirical inquiry that investigates a phenomenon where boundaries between the object of the case study and its surroundings are unclear (Yin, 2003). There is no singular agreed upon case study methodology; it is adapted to the situation at hand and can use qualitative methods, quantitative methods, or a combination of the two (i.e. using mixed methods research in a case study (Brannen, 2008)). It has been shown that it is possible to generalise from case studies (Flyvbjerg, 2006; Yin, 2003), countering a common criticism of case study methodology

(Bryman, 2008). Flyvbjerg goes on to state that "formal generalization is overvalued as a source of scientific development, whereas 'the force of example' is underestimated" (Flyvbjerg, 2006: 228).

4.1.2 Literature review

A literature review is a "systematic, explicit, and reproducible method for identifying, evaluating, and synthesizing the existing body of completed and recorded work produced by researchers, scholars and practitioners" (Fink, 2010: 3). The design of the literature review is dependent on the type of research questions that are asked (Booth et al., 2011; Fink, 2010), and numerous variants can be identified (e.g. critical review, mapping review, state-of-the-art review (Booth et al., 2011)).

Bryman (2008) makes a distinction between two types of literature review; systematic review and narrative review. The systematic review is based on using a procedural approach, with the intention of reducing bias and increasing reproducibility. This type of review can be used to identify knowledge gaps in an existing research field, thus providing research direction. The narrative review, on the other hand, is a "process of discovery" (Bryman, 2008: 93) and can be used when the research field is not defined in advance or there are a multitude of overlapping approaches. A distinction between these two types is that the purpose of the systematic review can be seen as accumulation of knowledge, whereas the purpose of the narrative review can be seen as generating understanding (Bryman, 2008).

A foundational skill for performing a successful literature review is the ability to search for, evaluate and use information (Booth et al., 2011). Searching for literature involves both how to search (keywords, search phrases) and where to search (libraries, peer reviewed journals, scientific search engines, online archives, etc.) (Bryman, 2008).

When presenting the results of a literature review, Wilkinson (1991) introduces a time perspective, distinguishing between historical and topical literature reviews. The purpose of the historical literature review is to provide a chronological understanding of the research field, whereas the topical provides a "state-of-the-art synthesis of all the pertinent research on the problem at that time" (Wilkinson, 1991: 126) with less or no regard to the publishing chronology. The presentation of the literature review is dependent on the purpose of the review (i.e. what is the research question?), the intended use (knowledge support or decision support) and the intended audience (e.g. assumed level of prior knowledge) (Booth et al., 2011).

4.2 Research tools

The analytical framework in the research design (box 3 in Figure 1) is based on an integrated use of the two research methods presented above and the five analytical and procedural tools presented below. By modifying Wrisberg's (2002: 36) framework for the supply of environmental information, a framework for the supply of CSR information can be created. The framework is shown in Figure 2. The framework shows the relationship between concepts for sustainability and tools for “reasoning, analysis and communication” (Wrisberg, 2002: 35). Originally developed as a framework for the supply of environmental information, the framework is broadened to include social aspects. This is done partly by adding new elements (e.g. CSR and systems thinking in the concepts box), partly by applying elements more broadly (e.g. including social aspects in LCA, not limiting the stakeholder analysis to environmental aspects only). The quality of the output is, as for all frameworks, dependent on the quality of the input data.

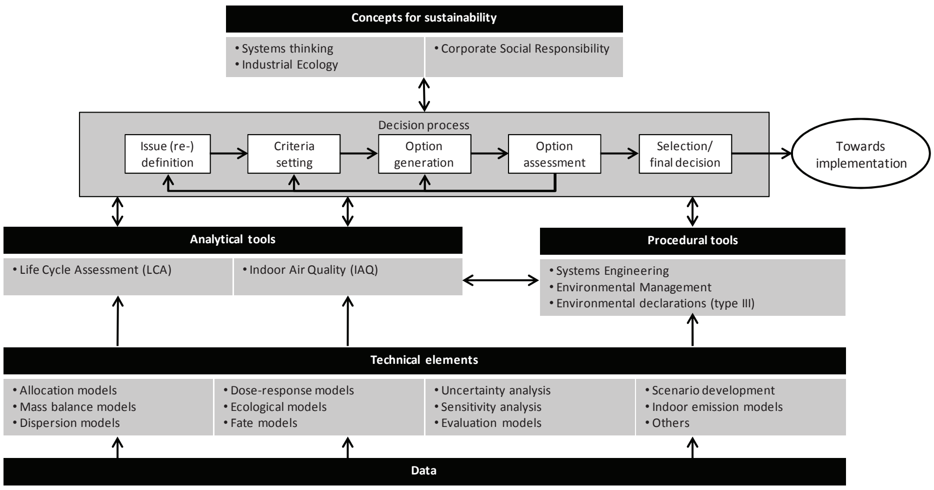


Figure 2: Framework for the supply of CSR information (modified from Wrisberg, 2002: 36)

The various elements of the framework have been selected through an iterative process throughout the case study. An example of this is the selection of Indoor Air Quality (IAQ) as a tool, which has been derived from the broader field of Occupational Health and Safety (OHS).

4.2.1 Systems Engineering

A system is “man-made, created and utilized to provide products and/or services in defined environments for the benefit of users and other stakeholders” (ISO, 2008b: 7). A system of interest is composed of sub-systems and system elements in interaction with each other (e.g. hardware, software, humans and economics). The intended purpose of the system is dependent on the observer; for a customer it may be delivering a product or service and for a shareholder it may be delivering a profit.

The Systems Engineering methodology (SE) takes into account all phases of the system life, from design and planning to operation and retirement (Fet, 1997). In the typical SE terminology the term *life cycle* differs from how it is used in for example industrial ecology. The SE *life cycle* is therefore here referred to as the *system life*, in order to distinguish between the two approaches.

Blanchard and Fabrycky (1990) have stated that it is important to create requirements for all phases in the system life and to view the system as a whole. Numerous authors have used systems engineering in an industrial ecology context (Fet, 2002; Fet et al., 2010; Haskins, 2008; Sopha et al., 2009). Numerous SE methodologies have been developed, for general or specific purposes (Haskins, 2006). Here an SE methodology that has been developed and tested within an industrial ecology context has been selected. The Fet six step SE process is a logical and sequentially iterative process (Fet, 1997, 2002), as described below.

Step 1: Identify needs

The first step is to identify the needs of the stakeholders. A stakeholder is commonly defined as an individual or an organisation that can affect or be affected by the system, but can also be defined broader for example by including the environment or elements of the environment as stakeholders (Haigh and Griffiths, 2009; Mitchell et al., 1997). Based on a general idea or an outline of the system, a stakeholder analysis is performed (Freeman, 2010). When the stakeholders have been identified, three questions guide the process onwards: What is needed? Why is it needed? How well must the need be satisfied? These questions attempt to address the underlying needs of the stakeholders (e.g. a car may be the stated need but the underlying need may be access to the workplace, which can be met by providing virtual office services or transport services, as long as the commute does not exceed a stated duration). In complex systems needs may be contradictory. This requires a process of sorting and ranking the needs of the individual stakeholders (Mitchell et al., 1997; Sparrevik et al., 2011).

Step 2: Define requirements

Requirements are defined by answering the three questions posed in step one. Requirements can be functional ('what?'), operational ('why?') or physical ('how?'). As the SE methodology is iterative, requirements should always be validated by the stakeholders themselves, for example through interviews or focus groups (Haskins, 2006).

Step 3: Specify performance

The third step is to identify measurable performance indicators and define the criteria these must meet. Criteria can either relate to how the system meets the needs of the stakeholders (effectiveness) or how the system meets the requirements established in step two (efficiency) (Sproles, 2000). Performance indicators should be objective and science based, where this is possible. Furthermore, they should be observable and quantifiable, valid, sensitive to change, compatible with other management indicators, transparent and robust against manipulation (Kjellén, 2000).

Step 4: Analyse and optimise

The requirements and specified performance are used to analyse and optimise the system, which in a sustainability context includes social and environmental impact over generations. Reflecting the iterative nature of the SE methodology, the analysis must begin with identifying a set of options that may satisfy the stakeholders' needs. Having selected a solution, subsequent iterations can focus on incremental improvements of the selected alternative.

Examples of analytical approaches that may be useful in this step are scenario analysis, back-casting, trade-off analysis, multivariate decision analysis and eco-/socio-efficiency.

Consideration must in this step be given especially to clarifying trade-offs and identifying benefits and detriments for the various stakeholders, as this is "the rule rather than the exception" (Hahn et al., 2010: 218) for business decisions involving economic, social and environmental aspects.

Step 5: Design, solve and improve
The fifth step is iterations over system design, solution and improvements. This step can concern the entire system, individual sub-systems or connections between sub-systems. Changes made here can lead to going back to previous stages to request clarification or acceptance for solutions with stakeholders, or redesign of requirements and performance indicators.

Step 6: Verify, test and report
The sixth and final step is verification, testing and reporting. Verification concerns both the effectiveness and the efficiency of the system, and is evaluated against the specified performance criteria. The results are subsequently validated with the stakeholders. This is an integral part of the SE methodology; requirements must be testable, and performance indicators and criteria must therefore be designed with verification in mind.

4.2.2 Environmental management

The activities of organisations have a direct and indirect impact on the environment, where direct refers to impact from activities in the organisation and indirect means impact from activities elsewhere in the value chain. The purpose of an environmental management system (EMS) is to work systematically with these impacts, with a strong focus on continual improvement (so strong it has even been termed "the soul of the machine" (Brouwer and van Koppen, 2008: 450)). The rationale for the environmental management system is the organisation's environmental strategy. The environmental strategy furthermore dictates the ambition level, for example to comply with legal requirements, or to gain a competitive advantage through excellence.

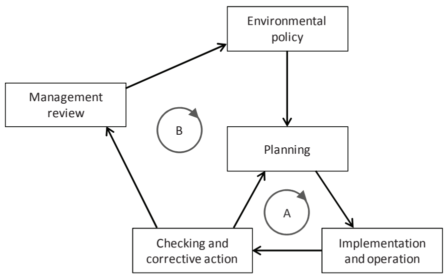


Figure 3: Short-term (A) and long-term (B) improvement cycles (Heida & Hortensius in Brouwer and van Koppen, 2008)

A feedback loop is needed in order to ensure continual improvement. The plan-do-check-act (PDCA) cycle is one such feedback loop, and it is the basis for two of the most recognised environmental management tools: the ISO 14001 standard (ISO, 2004a) and the EMAS regulation (European Commission, 2012a). Continual improvement should not only focus on the operational level (short-term, tactical improvement cycle) but also on the system itself (long-term, strategic improvement cycle) (Brouwer and van Koppen, 2008), as shown in Figure 3. In the ISO 14001, the PDCA cycle consists of five steps (ISO, 2004a; Viddal et al., 1997):

Define an environmental policy

The environmental policy defines the scope of an organisation's environmental management system and establishes the framework within which objectives and goals are established. Core requirements are adhering to legal requirements, committing to continual improvement and communicating the environmental policy to stakeholders. Legal requirements can be extended to include soft law (e.g. Agenda 21 from the UN's Rio conference in 1992), if the organisation so chooses. Continual improvement includes revising the policy itself. The extent of the policy is dependent on "the nature, scale and environmental impacts of its activities, products and services" (ISO, 2004a: 11). Defining the environmental policy is the responsibility of the organisation's top management, and it shall be made publicly available.

Planning

The first step in planning is to identify activities that are interacting or can interact with the environment (such activities are termed *environmental aspects*) and determine which aspects are significant (i.e. have or can have a significant environmental impact). The second step is to identify all legal requirements (including soft law) and relate these to the environmental aspects. Objectives, targets and programmes are subsequently implemented based on this knowledge, with defined means, measures and time-frames. Environmental aspects include the organisation's products and services as well as aspects outside of the organisation that it can control or influence, and ISO 14001 thus links the environmental management system to the value chain (Lewandowska et al., 2011; Nawrocka et al., 2009) (although this is not always the case in practice (Ammenberg and Sundin, 2005)).

Implementation and operation

The first steps in order to implement an environmental management system are to define roles and responsibilities, and to provide sufficient resources (e.g. human, organisational, financial, knowledge resources) for operating and improving the system. This also includes appointing a top management representative who has the responsibility for the environmental management system and for reporting to the top management on the performance. Based on the knowledge of environmental aspects, all persons who can potentially cause significant environmental impact are identified. The competence of these persons must be assessed and documented, and training or education provided when needed.

The organisation must establish procedures for communication between levels and functions within the organisation, as well as for receiving, documenting and responding to external stakeholders (but communicating on environmental aspects to external stakeholders is voluntary according to the standard). The environmental management system must be documented, including the policy, a description of the main elements of the system and the interaction between them, and interaction with the reference documents (e.g. laws). This documentation must be dealt with systematically and reviewed periodically.

The next step is to ensure operational control through the planning and carrying out of activities that are associated with significant environmental aspects. The purpose is to avoid deviations from goals and objectives. This extends to having procedures for emergency response, and periodically testing these procedures.

Checking and corrective action

Having established an environmental management system, it must be monitored and measured against the internal requirements (defined goals, targets and objectives). The system is furthermore evaluated for compliance with external requirements (e.g. legal). Corrective and preventive actions are taken when needed. Furthermore, this step includes control of records that demonstrate conformity to the internal and external requirements. The system must be audited regularly. This audit may be internal, performed by objective and impartial auditors. Results of the audit must be presented to the top management.

Management review

The final step in the PDCA cycle is management review. This must be performed on a regular basis, founded on the results of audits, internal and external communication, environmental performance, changing circumstances, etc. The review may result in changes in any part of the management system, for example objectives, targets, procedures and evaluation of environmental aspects.

It has been recommended that an environmental management system should not be a stand-alone system, but be integrated with other management systems (e.g. quality, food safety) (Bernardo et al., 2009; Jørgensen, 2008; Jørgensen et al., 2006). This has also been advocated by ISO, for example through practical guidelines for integration (ISO, 2008a) and coordination of the standards themselves (ISO, 2011). Other recommendations have been to integrate environmental management across organisations, for example in the supply chain (Curkovic and Sroufe, 2011; Mueller et al., 2009; Nawrocka et al., 2009; Seuring and Müller, 2007).

A critique of environmental management systems based on the PDCA cycle is that the focus on continual improvement can lead to only minor improvements taking place, and that this is also reflected in research on environmental management systems (Ählström et al., 2009). This shows the need for continual improvement of the system itself after it is implemented, not just of the goals and objectives within the system (Brouwer and van Koppen, 2008).

4.2.3 Life Cycle Assessment (LCA)

The purpose of Life Cycle Assessment (LCA) is to provide objective and science based information about the environmental impacts of products (including services). LCA calculates the environmental impact from a product or a service over the whole life cycle, from raw material extraction through production, use, recycling and disposal (Bauman and Tillman, 2004; Institute for Environment and Sustainability, 2010). Two ISO standards have been developed for LCA, the ISO 14040 (ISO, 2006b) concerning principles and framework and the ISO 14044 (ISO, 2006c) concerning requirements and guidelines. These two standards have been recommended to "serve as core reference documents for the users and practitioners of LCA" (Finkbeiner et al., 2006: 85).

Environmental aspects in LCA

According to the ISO standards, LCA is an iterative process with four stages.

Stage 1: Goal and scope

The goal definition in an LCA is a description of the intended use of the results, the reasons for doing the LCA and identification of the intended audience. The scope describes the functions of the analysed product system (for example, the function of a furniture production system can be defined as to provide seating), defines the system boundaries and defines the functional unit (FU) (a quantified reference unit, for example, the provision of seating for 15 years). The functional unit is used to determine the scale of reference flows, for example the number of chairs needed to provide seating for 15 years (e.g. 0.5 chairs for a chair of high quality or 5 chairs for a chair of low quality). This determines the scale of inputs and outputs in the product system. The scope furthermore defines requirements for other elements in the analysis, such as data quality, allocation procedures, assumptions, need for and type of critical review, etc. As LCA is an iterative approach, the scope of the study may be modified based on new knowledge.

Stage 2: Inventory analysis

In the Life Cycle Inventory (LCI) stage the inputs and outputs of the processes in the product system are collected and quantified, including information on data quality, uncertainty and variability. This includes inputs and outputs within the technosphere (e.g. products, co-products, wastes) and inputs from and outputs to the environment (termed *elementary flows*). Elementary flows can be inputs and outputs of resources (materials or energy), emissions to air, land and water, as well as other environmental aspects (e.g. land use change).

The modelling of the system (consisting of sub-systems and processes) is dependent on the requirements from the goal and scope definition, for example if specific data is gathered or if generic data from background databases are used (e.g. industry averages, national averages).

Stage 3: Impact assessment

The purpose of the Life Cycle Impact Assessment (LCIA) stage is to identify the most significant impact categories and the sources of these (e.g. from which sub-system, which process, which type of emissions, etc.). There are five steps in impact assessment: 1) definition of impact categories (e.g. global warming, acidification, human toxicity, etc.), 2) classification (determining which impact categories an input or output may contribute to), 3) characterisation (quantifying the contribution, e.g. in CO_2-equivalents for emissions contributing to global warming), 4) normalisation (relating the impact to a known value, e.g. total national or industry impacts) and 5) weighting (determining the relative significance of the impact categories, providing a single value result). As the purpose of an LCA is to provide objective and science-based information, the ISO 14044 warns that weighting procedures are "based on value-choices and are not scientifically based" (ISO, 2006c: 22), and recommends including information on how the weighting was performed if this step is included in the impact assessment.

Stage 4: Interpretation
Interpretation is a significant element in LCA, and at every stage interpretation of the results may lead to revisions of the LCA. In addition to this, interpretation is also a separate stage in the ISO standards, where the final results are interpreted. Here the most significant issues from the inventory and impact assessment stages are identified and the quality of the LCA itself is evaluated (with regards to completeness, sensitivity, application, etc). The interpretation stage is intended to provide the intended audience with information on the conclusions and limitations of the LCA, as well as recommendations.

Social aspects in LCA
The purpose of an LCA performed in accordance with the ISO standards is to analyse environmental impacts from products in a life cycle perspective, in order to avoid problems shifting from one site to another and from one type of environmental impact to another. This is similar to looking only at the green arrows in Figure 4. Although the ISO standards are limited to environmental impacts, attention has increasingly been given to problems being

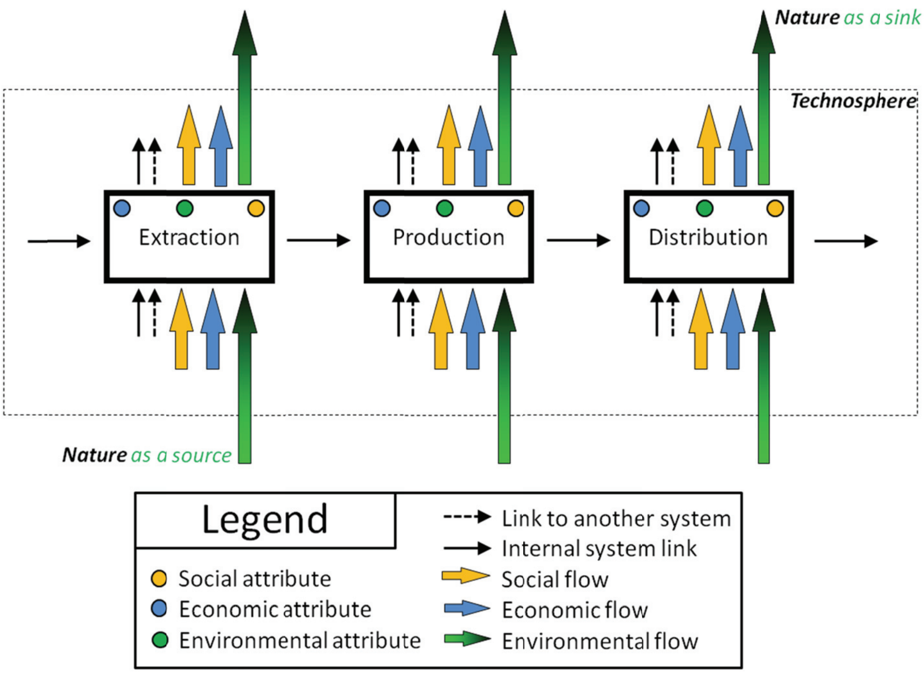


Figure 4: A simplified partial life cycle with economic, social and environmental flows and attributes

shifted from environmental aspects to social aspects, giving rise to the need to expand the LCA methodology to include social impacts (Benoît et al., 2010; Grießhammer et al., 2006; Hutchins and Sutherland, 2008; Jørgensen et al., 2009; Jørgensen et al., 2008; Norris, 2006). There is no agreed upon methodology on how social aspects should be included in LCA (Curran, 2008), but numerous approaches have been proposed. UNEP/SETAC have developed guidelines for social life cycle assessment (S-LCA) (UNEP/SETAC, 2009); guidelines that are still being developed further (Benoît-Norris et al., 2011). Other approaches include life cycle attribute assessment (e.g. use of certifications or management systems, adherence to codes of conduct or principles) (Andrews et al., 2009; Norris, 2006) or developing new impact pathways to existing LCA indicators for human health (e.g. DALY, QALY) (Pettersen and Hertwich, 2008). Parent (2010) makes a distinction between approaches that use impact pathways similar to the way impact is calculated in environmental assessments (e.g. DALY, QALY) and those that do not (e.g. UNEP/SETAC, attribute assessment).

When integrating social aspects into an LCA, the principles for selecting system boundaries should be identical for social and environmental aspects (Curran, 2008; Weidema, 2005). Furthermore, including social aspects in LCA requires a higher level of stakeholder integration (Grießhammer et al., 2006).

4.2.4 Indoor Air Quality (IAQ)

Indoor Air Quality (IAQ) can be defined as tools concerned with "the physically measured air quality (concentrations) and/or the perceived air quality (e.g. the odour intensity)" (Dokka, 2000: 6). IAQ is here further limited to emissions contributing to the physically measured air quality, combining emission measurements with emission modelling, as described in Paper 6. Perceived air quality is not addressed here.

IAQ is a toolbox within Occupational Health and Safety (OHS). OHS is understood as a broad set of procedural and analytical tools that are used to systematically describe, analyse and improve workplaces issues. ILO and WHO have defined the goals of OHS as promoting and maintaining well-being through protection from risk and adaptation of work and the workplace (Stellman, 1998). It is not singularly defined, but is related to issues of health, safety and welfare (Erickson, 1996; Montero et al., 2009). Originally focusing on the workplace, Erickson states that "it is increasingly difficult (if not irrelevant) to differentiate between *occupational health* and *environmental health,* or even *human health* from *environmental quality*" (Erickson, 1996: 4), as illustrated in Figure 5.

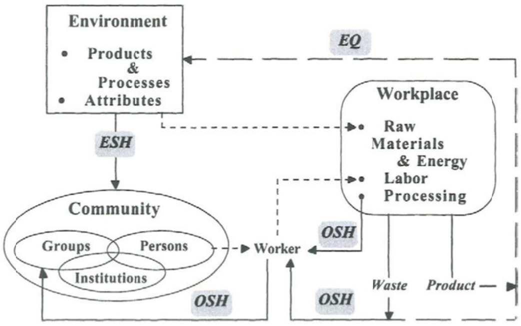


Figure 5: OHS related to workplace, environment and society (Erickson, 1996: 4)

OHS tools can be applied separately or integrated within other tools, e.g. LCA (Hellweg et al., 2009; Hofstetter and Norris, 2003; Pettersen and Hertwich, 2008; Skaar and Jørgensen, 2012), CSR (Montero et al., 2009; van Tulder et al., 2009). OHS is here limited to analytical tools that are used to gather and calculate information about health aspects in the value chain. In the case study this is related to measuring and modelling indoor emissions and estimating their toxicity (see Paper 6).

4.2.5 Environmental Product Declarations (EPD)

The following section is a summary of Paper 1. See Appendix 1 for full text of the publication.

There are a multitude of environmental labels and declarations currently in use for products (where products are understood as any goods or service) (ISO, 2000a). The International Organization for Standardization (ISO) 14000-series distinguishes between three different types of declarations, which all require that life cycle aspects are taken into consideration. These are: Type I programmes, i.e. multiple criteria-based, third party programmes awarding labels claiming overall environmental preferability (ISO, 1999b), Type II programs, i.e. self-declared environmental claims where life cycle considerations are taken into account (ISO, 1999a), and Type III programmes (ISO, 2006a). The Environmental Product Declaration (EPD) is a Type III environmental declaration and is discussed here.

To obtain a Type III Environmental Product Declaration (EPD) the requirements are to conduct a Life Cycle Assessment of the product in accordance with the ISO 14040-standards series (ISO, 2006b, 2006c), and receive a third party verification of the LCA and the EPD. Characteristics of Type III EPDs are that they give objective and quantified environmental information, and that they shall allow comparison of products fulfilling identical functions. It should be noted that there are no environmental performance requirements for a product to get an EPD.

An EPD is based on Product Category Rules (PCR), which define the criteria for a specific product category and set out the requirements that must be met when preparing an EPD. The PCR aims to identify and define rules for the process of creating an EPD, in order to enable a comparison between products. The PCR must therefore:

- identify the functional and performance characteristics of the product
- define the criteria to be used in the LCA study of products belonging to the category
- specify the information that must be reported in the EPD

A PCR must comply with the requirements of ISO 14025 and the ISO 14040-series on LCA. In addition, specific technical standards for the relevant product must be fulfilled and information about this shall be listed in the declaration. The development of a PCR-document should follow these steps (ISO, 2006a):

1. Define product category
2. Produce an appropriate product category background LCA, in order to identify the most significant environmental aspects and impacts of the product category
3. Specify rules, parameters and requirements for reporting, and how to produce the data required for the product declarations

Further details on point 3 above can be found in Paper 1 and in the ISO 14025 standard (ISO, 2006a). An approved PCR is valid for a defined period of time (e.g. 3 years). The content of an EPD is specified in the ISO standard, but there are no requirements for the format.

The ISO standard requires that an EPD programme is established to prepare, maintain and communicate the programme instructions. Further tasks are to publish the PCRs and EPDs, establish review procedures and monitor related Type III programmes. (ISO, 2006a). An additional goal of the standard is to stimulate the establishment of verification systems for EPDs. In developing a Type III EPD programme the rules for verification shall be set up in accordance with ISO 14020, ISO 14025 and the ISO 14040-series. The programme operator shall also specify the accreditation requirements for verifiers. A verification procedure shall include the format of verification, its documentation, verification rules and verification results. For verification of EPDs, the verifier shall verify the quality, accuracy and completeness of the data, and in addition, the conformance to the PCR. The verification of LCA data in the EPD shall confirm conformance with the PCR and the ISO 14040 series standards. Verification systems can vary between different programme operators.

To ease the verification-process a database or set of databases can be verified, and the verification of the EPDs could therefore be simplified to only cover verification of the in-house procedures on how the EPDs are made for the products. Such procedures should be a part of the company's environmental management system, and should include "Procedure for identification of environmental aspects of one's own products", "Procedure for achieving environmental product information at sub-suppliers", "Procedure for the development of the EPDs using a verified and industry specific database". According to ISO 14025 (ISO, 2006a) it is possible for independent verification of the EPDs to be carried out by the companies own environmental auditors, provided that the company has an ISO 14001 or EMAS-certified environmental management system and that the certification body has approved the LCA routines as part of the management system.

4.3 Quantitative indicators

The tools presented above are based on a quantitative approach, using performance indicators to describe and assess environmental and social aspects. Before proceeding to the presentation of the case study, it is important to understand the context for the use and presentation of indicators. This is in particular relevant considering that the terminology of the bottom-up indicators of corporate reporting usually is not the same as used for the top-down indicators of national and regional environmental sustainability reporting.

For the analytical tools of LCA and EPDs indicators are first needed at the inventory level, quantifying flows of inputs (energy and material resource consumption) and flows of outputs (wastes and emissions to air, land and water). Subsequently all flows are classified in impact categories (pre-selected in the PCR in the case of the EPD) and aggregated to a single value for each impact category. Aggregation within an impact category is done by using characterisation factors (e.g. measuring global warming potential in CO_2 equivalents), with all inputs and outputs contributing to an impact category related to a reference. Identifying and measuring social aspects and aspects of the extended value chain have in the case study also been focused on selecting quantified performance indicators to include in the product declaration. The performance indicators can also be used in procedural tools, for example in systems engineering to specify requirements and evaluate performance and in environmental management systems to evaluate both operational and management performance. Performance indicators can be used to describe any of the three systems of interest (the corporation, the extended value chain and the product life cycle), but the prevalent approaches focus on either the first and last systems (see Paper 4).

When discussing indicators it is useful to have a typology to base the discussion on. Here an indicator typology is used that is mainly based on a combination and adaptation of the typology used by the European Energy Agency (EEA) (Smeets and Weterings, 1999) and the typology in the ISO 14031 standard for environmental performance evaluation (ISO, 2000b). These were originally developed for environmental indicators, but are also relevant for economic and social indicators. Table 2 shows the relationship between the terms used here and the terms used in the ISO 14031 and by the EEA. EEA uses the Driving forces-Pressures-States-Impacts-Responses (DPSIR) framework, and as the DPSIR framework is very comprehensive the relationships shown in the table are not absolute but show the main categories they are considered to belong in. This is not an exhaustive list of typologies and there are numerous approaches to classifying indicators (e.g. leading, lagging and distance-to-target indicators). These two typologies have been selected because they harmonise with the LCA and EPD tools.

Table 2: Indicator terminology

Thesis terminology	ISO 14031 terminology	EEA terminology
Descriptive	Environmental Condition Indicator (ECI)	State, Pressure and Impacts
Performance: OPI	Operational Performance Indicator (OPI)	State, Pressure and Impacts, linked to targets
Performance: MPI	Management Performance Indicator (MPI)	State, Pressure and Impacts, linked to targets
Efficiency	Not addressed in ISO 14031. The ISO 14045 term is eco-efficiency indicator (ISO, 2012).	Relationships between DPSIR elements (e.g. the relationship between D and P as an eco-efficiency indicator)
Composite indicators	Indexed indicators, aggregated indicators and weighted indicators	Total welfare indicators

The five main types of indicators are intended to answer four questions: what is happening? (descriptive indicators); what are we doing? (performance indicators); are we improving? (efficiency indicators); and are we better off? (composite indicators). Of these only the operational performance indicators are included in a standard EPD, where they become a type of efficiency indicators when related to the functional unit of the product. Descriptive indicators are not included in the EPD, but are helpful for EMS in order to identify significant environmental aspects and to interpret results in LCA. Composite indicators require value based weighting in order to combine multiple impact categories into a single score indicator. Composite indicators may be included in an LCA but are typically not included in an EPD, and the procedures for developing composite indicators are in the ISO 14040 and ISO 14044 described as having “no scientific basis” (ISO, 2006b: 13, 2006c: 11). To go beyond reporting, performance indicators for products must be integrated in a continual improvement process that can link the product to the larger system.

The quality of a performance indicator can be evaluated using a set of requirements, for example as shown in Table 3.There are many ways to distinguish between types of indicator requirements. One way is to distinguish between scientific requirements (how good is the indicator) and pragmatic requirements (how usable is the indicator). Table 3 provides an overview of general requirements for a good indicator, from the fields of sustainability (Burgherr et al., 2005), risk management (Kjellén, 2000) and CSR (Zadek, 2007). For the EPD, the requirements in the ISO 14025 are more focused on scientific requirements, with objectivity being a primary concern.

When quantified performance indicators are used to provide information on environmental and social aspects in the value chain, allocation and aggregation techniques are needed to provide pertinent information on the whole value chain. Allocation and aggregation issues are standard techniques in an environmental LCA, and allocation is defined in the ISO 14040 as "partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems" (ISO, 2006b: 7). Aggregation can be regarded as the opposite process, where indicators measuring the same aspects are combined into a single value. If the indicators are not measuring the same aspect, then the aggregation technique becomes a weighting technique (as described in Section 4.2.3).

Table 3: Indicator requirements

Scientific requirements	Pragmatic requirements
Observable and quantifiable	Easily understood
Content validity	Simple
Criterion-related validity	Relevant
Construct validity	Timely
Sensitive to change	Manageable
Compatible with other indicators used	Compelling
Transparent and meaningful	Comparable
Robust against manipulation	Feasible
Verifiable	
Appropriate in scale	

In the ISO 14040 allocation and aggregation concerns only physical flows. A recommended allocation procedure is presented in ISO 14044 (ISO, 2006c), which can be reversed to provide an aggregation procedure. A challenge arises when it is not physical flows that are measured, but rather attributes related to a production process (for example if the product is produced with an environmental management system present, as Andrews et al. (2009) have examined). Physical flows can be added together, providing a simple aggregation technique (for example calculating the aggregated energy demand of a system by adding together the energy demand for its separate processes). When it comes to aggregation of attributes, there is no simple additive solution. Instead we need to find a common measure (e.g. value added, cost, working time, energy consumption) for the attributes that allow us to aggregate them through the value chain. This will always be a value based method. Aggregation is performed in this manner in order to analyse questions such as 'how much of the value chain has management systems in place for environmental and occupational health aspects?' and 'do the workers receive fair pay?' (Skaar, 2010).

5 Case study and research results

5.1 Overview of furniture case

A longitudinal case study has been performed in the Norwegian furniture industry. The case study is based on the activity within and surrounding a number of interconnected research projects conducted from the Industrial Ecology programme at NTNU and lead by Professor Annik Magerholm Fet (Fet et al., 2005a). These research projects have varied in length and number of involved companies, but four companies participated with their time and resources over a longer time period and are here considered as the core case companies, see Table 4. The time period covered here is between 2005 and 2010, which overlaps the PhD research, and is a part of a longer stream of research concerned with sustainability in the furniture industry, starting before 2000 and continuing beyond 2010.

Table 4: Core case companies

Company	Products and market (general)	Products in case study
Helland Møbler AS	Contract market, office furniture	Selected chairs and tables
Ekornes ASA	Home market and contract market, chairs, beds and mattresses	Selected chairs
Jensen AS	Home market and contract market, beds and mattresses	Selected beds and mattresses
Håg ASA	Contract market, office chairs	No products

The Norwegian furniture industry consists mainly of small and medium sized enterprises (<250 employees), with a limited number of larger companies. The case companies are among the larger in the industry. In 2010 there were approximately 500 furniture manufacturing companies in Norway, employing 8000 and with a turnover of 10 billion NOK (≈1.3 billion Euro). Geographically, the furniture companies are concentrated in the south of Norway (2/3 of companies) and in the county of Møre and Romsdal (1/3 of companies). The types of furniture produced by the case companies are in all sizes and made from a large variety of materials (wood, wood/metal, metal/plastic, plastic).

Below the furniture value chain is introduced first, followed by an overview of the four phases of the case study, which in turn is followed by a presentation of the two tools developed in conjunction with the case study, viz. software with a database for documenting environmental and social performance of products, and a method for integrating the impact on human health of indoor emissions from furniture into LCA.

5.2 The furniture value chain

The main purpose of the furniture value chain is defined in this research as providing the function of seating to the furniture company's customers. Secondary functions are related to the performance of the product (e.g. strength, comfort, durability, environmental impact, social impact). Tertiary functions are related to the aesthetics of the product (e.g. colour, design). Only primary and secondary functions are considered in the case study.

A schematic view of the material value chain for a piece of furniture is shown in Figure 6. The total value chain can be seen as a system consisting of several sub-systems. The material flow is indicated by the direction of the arrows. A distinction can be made between upstream and downstream processes, where upstream processes occur to the left of the production sub-system, downstream processes to the right. The most easily accessible parts of the value chain in this case are the suppliers. The manufacturing company knows what it buys, from whom it buys and, in most cases, is in a position to demand environmental information, depending on the power balance in the buyer-supplier relationship (e.g. as discussed by Michelsen (2006)). This may also be the case for the distribution sub-system. In a business-to-business market with institutional buyers, the manufacturer has direct contact with both distributors and end users. The case companies that are in the business-to-consumer market do not have direct contact with the end users; the distribution is commonly done through channels not controlled by the manufacturer.

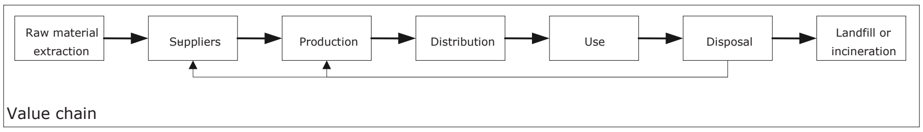


Figure 6: The material value chain, modified from Fet et al. (2005b: 2)

The part of the value chain that is of special interest is defined as the point of entry (Kaplinsky and Morris, 2000). In the furniture value chains analysed here the point of entry is the furniture manufacturer. Figure 7 shows the key stakeholders of the furniture value chains, seen from the furniture manufacturer's perspective, which through the case study have been found to be suppliers, customers and authorities. The value chain is dominated by a product focus, and in light of this local communities and the public (i.e. through NGOs) are not considered primary stakeholders.

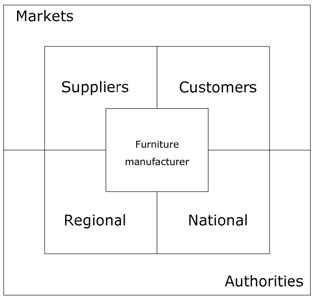


Figure 7: Stakeholders observed from a manufacturer's point of view

The realisation of the Production sub-system in Figure 6 is unique to each case company. An initial assumption was that the manufacturing was similar from one company to another. The case study has shown that this is not the case; the processes that are performed by suppliers and sub-suppliers in one value chain may be an integrated part of the manufacturing company in another value chain, confirming the need to look at the whole value chain and not just the production process of the manufacturing company. In its simplest form Production is limited to the assembly of components and packaging of products, and in the most complex it includes manufacturing of components such as wood laminates, manufacturing of steel frames and chemical production such as polyurethane foam. Similarly, the Distribution sub-system (including distribution and retail to customer) can in one value chain be partially performed by the furniture manufacturing company itself, whilst in another value chain this is done entirely by external distributors.

The system boundaries of the furniture material value chain cover raw material extraction and production, processing, use and maintenance, transportation, recycling and ultimate disposal. Production of capital goods, infrastructure and personnel related activities are included where relevant (e.g. energy production systems). Inputs and outputs crossing the boundary between the system and nature are labelled elementary flows. Flows related to recycling processes are allocated between the furniture value chain and other production systems (e.g. district heating system, where relevant).

A guiding principle for deciding which inputs and outputs are to be included in the assessment of the product life cycle is found in guidelines for the Norwegian EPD Foundation (EPD Norway), which states that processes and activities that contribute to less than ±1 % of the total environmental impact (based on a priori expert judgment) in selected impact categories may be omitted from the study (EPD Norway, 2009b), a guiding principle also found in the PCR for seating (EPD Norway, 2008). The extended supply chain is defined as all the organisations that are responsible for the processes that have been included within the system boundaries. Similarly, social aspects should also be considered within the same system boundaries. Boundaries may be refined, for example if it is discovered that significant social impacts are excluded. This has, however, not been necessary in this case study.

5.3 Case study evolution: iterations on a theme

The starting point for the case study was a number of furniture manufacturers' stated need to document the environmental performance of their products in order to meet demands from customers in the business-to-business market. Additional expectations were that EPDs could be used to meet demands from authorities, win contracts, better understand the environmental performance of their products subsequently use this knowledge in product development (Skaar and Fet, 2006). This scope was broadened over time to include social aspects (Fet et al., 2009b). The Systems Engineering methodology was used to develop solutions to the industry needs. Each implemented solution creates to a new situation with specific needs and requirements, which are the starting point for developing an improved solution. Several phases can be identified in this process, each starting with an initial need that is analysed and attempted to be satisfied. Table 5 below provides an overview of the four phases in the case study, with phases shown in the first column. The first phase is the development of a modular approach to documentation of environmental aspects of the product life cycle, the second phase is streamlining the user interface, the third phase is simplified verification and the fourth phase is human health aspects from indoor emissions.

These phases were identified in retrospect, and in time the second and the fourth phase were started in parallel. The table for each phase is structured according to the six steps in the Systems Engineering methodology, with the linkages to the six steps indicated in the top row. The first two steps (1: needs, 2: requirements) are addressed in the second column and the third step (3: requirements) is addressed in the third column. The final three steps (4: analyse and optimise, 5: design, solve and improve, and 6: verify, test and report) are addressed together in the column labelled 'Solution'. A quantified verification against the needs and requirements was not conducted. The contribution to the research outcome and links to research publications from each phase is shown in the rightmost column. The solutions for each stage were evaluated through meetings and dialogue with key stakeholders in the research community, the furniture industry and the Norwegian EPD system. The end users (e.g. customers or procurers) were only indirectly involved.

Table 5: Overview of four phases in the case study (with the main time period of each phase indicated)

Initial need and requirement ***(step 1 & 2 in SE)***	Specified performance ***(step 3 in SE)***	Solution ***(step 4, 5 & 6 in SE)***	Contribution to research outcome
Phase I: modular approach to documentation of the environmental aspects of the product life cycle (2005-2007)			
Provide documentation on environmental performance of products to customers	Modular LCI database that can be used to create EPDs for a range of products, based on company and value chain specific information	Prototype of modular EPD creation software in Excel/Word + PCR for four product categories	Presentation of the EPD system and development of methodology for modular approach to EPD generation. Results presented in Paper 1 and Paper 2. PCR presented in Appendix 7.
Phase II: streamlined user interface (2007-2009)			
Streamline the EPD creation process	Modular LCI database and stand-alone software	Development of the Data Assisted Tool for Sustainability Product Information (DATSUPI), a module based EPD creation software	Testing of methodology and software in furniture companies. Results presented in Paper 3 and Paper 4.
Phase III: simplified verification (2008-2010)			
Streamline the verification process	Integrate the EPD with the EMS, using a verified LCI database and verified procedures for creating EPDs	DATSUPI + ISO 14001 + verified LCI database	Improving EPD generation methodology and software, based on results from testing in phase II. Results presented in Paper 5.
Phase IV: human health aspects from indoor emissions (2007-2012)			
Address concerns regarding chemical usage in production and final product	Develop EPD beyond requirements of ISO 14025	Chemical assessment: additional section in EPD. Human health impact: additional impact category.	Development and testing of methodologies for addressing chemical use in the production phase and of methodology for quantifying and integrating indoor emissions in the use phase in an LCA. Results for production phase presented in Paper 5. Results for use phase presented in Paper 6 .

5.3.1 First phase: modular approach to documentation of the environmental aspects of the product life cycle

Furniture manufacturers were faced since before the turn of the millennium with increasing demands to document the environmental performance of their products in order to participate in the business-to-business market, and in particular public procurement. An example of the manifestation of this demand is the amendment to the Norwegian law on public procurement in 2001, requiring consideration of life cycle costs and environmental impact (FAD, 1999). Similar demands were also present in the private market, particularly in the contract market. As a result, the furniture manufacturers needed to document the environmental performance of their products. The requirement was to have a system that can meet the non-uniform demands from customers and allow comparison between products. Furthermore, the system must take into consideration the limited resources (time, capabilities) that are characteristic for the SME companies in the furniture industry.

A modular system based on Environmental Product Declarations (EPDs) (ISO, 2006d) was selected as an approach that had the potential to satisfy the needs of the furniture industry. Modularity here means modularity in the LCA data, with materials and components structured as cradle-to-gate LCA modules (i.e. per kg or per component). The modular approach was chosen because previous LCA studies in the furniture industry had identified that the materials and components production had a higher environmental impact than the furniture manufacturing process itself. Furthermore, a number of key suppliers were common in the entire industry (e.g. four producers dominated the domestic polyurethane foam market and two textile producer dominated the domestic textile market). Having EPDs for 80 % of the production of the four case companies was defined as a success criterion for the EPD generating system (Fet et al., 2006).

The EPD was chosen because it is intended to provide objective information on specified environmental aspects for products, based on LCA. Environmental aspects that are included in an EPD are specified in the PCR, and cover Life Cycle Inventory (LCI) data (consumption of material and energy resources and emissions to air, water and soil), selected environmental impact categories (e.g. climate change, depletion of the stratospheric ozone layer, acidification of land and water sources) and other data (e.g. types and quantities of wastes) (ISO, 2006d).

Having selected the EPD system, it was necessary to develop PCR documents for the relevant furniture types, in order to fulfil the requirements of the ISO 14025 standard and EPD Norway. The first step when preparing a PCR is to perform a survey to find if there are existing PCRs that fit or can be adapted. For the product group 'seating' no other English language PCR was found, making this the first of its kind. The PCR for seating can be found in Appendix 7. In addition to seating, the researcher contributed significantly to the development of PCR documents for beds and mattresses (EPD Norway, 2005), tables (EPD Norway, 2009a) and upholstery textiles (EPD Norway, 2006). Only seating is considered in the case study.

A modular LCA database was constructed (Skaar, 2005). This database was based on collecting specific data, generic data found in commercially available databases and inventory from previous LCAs in the Norwegian furniture industry. For the furniture manufacturers, the data for production was based on their annual environmental reports, with additional data collected when required. A prototype of the EPD generation software was created based on Microsoft Word and Microsoft Excel, and this prototype was rolled out in the industry (Fet et al., 2006).

The prototype was tested in the four case companies. At the end of this phase, 78 % of the furniture (in percentage of turnover) had EPDs, proving the efficiency of the approach against the pre-defined performance criteria (Skaar and Fet, 2006). The effectiveness (e.g. winning contracts and improving the environmental performance) was not tested due to resource limitations.

Based on the results of the prototype, three new needs were identified: streamlining and mainstreaming the user interface, simplifying the verification procedures and integrating human health aspects (from chemical use and product emissions). The efforts to meet these needs are addressed as three separate phases below.

5.3.2 Second phase: streamlined user interface

The experience the case companies had with using the prototype showed that there was a need for a more streamlined user interface. Three requirements to the software itself were developed in cooperation with the case companies. The first was to allow for a higher degree of modularisation when entering input (e.g. possibility to define modules such as 'armrest' or 'medium sized chair base', and re-use these modules in other products). This added a new dimension to modularity, which can provide modularity in product modelling in addition to the modularity in the LCA data established in the first phase. The second requirement was to allow updating the LCI data without migrating previous user input and with little expertise needed. The third requirement was enabling a higher degree of customised databases (each company using the software limiting access only to pertinent data sets).

The solution developed to meet the needs and requirements was the software Data Assisted Tool for Sustainability Product Information (DATSUPI), a module based software that is intended to be used by manufacturing companies to document the environmental and social performance of their products (Skaar et al., 2009). It is based on cradle-to-gate, gate-to-gate and gate-to-grave data modules with environmental and social performance indicators for materials and processes. For the environmental aspects, all LCA modelling is performed in the GaBi software based on specific data from manufacturers, suppliers and sub-suppliers, as well as generic databases. The resulting LCI data for materials and processes are transferred to DATSUPI.

There are a number of requirements that the DATSUPI software must meet in order to produce verifiable EPDs that are in accordance with ISO 14025 (ISO, 2006d) and the guidelines of EPD Norway (2009b). The specific requirements are found in the PCR (EPD Norway, 2008), and it is used to guide the process from data collection to final EPD. Figure 8 shows the role of the PCR in the data flow from LCA to final EPD when using DATSUPI. The PCR is used to first define the rules and requirements for performing the LCA in GaBi (PE International, 2011). Then the PCR defines the type of information that must be exported to DATSUPI (which inputs and outputs, which life cycle stages, etc.). When the user enters the product specification (types and amounts of materials, components and processes), this must be scaled to the functional unit defined in the PCR. Finally, the PCR defines the content of the EPD (however, the PCR does not specify the format of the EPD).

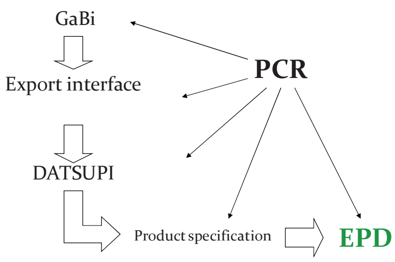


Figure 8: The role of the PCR in the GaBi-DATSUPI data flow

Figure 9 below shows details of the data flow for the environmental aspects as going between the furniture manufacturer, the LCA software (GaBi) and DATSUPI (shown in Figure 8 as the flow GaBi → Export interface → DATSUPI). The figure shows how specific data from manufacturers, suppliers and sub-suppliers are combined with generic data from databases to create the modular LCI inventory in GaBi. Then the environmental impact for each module is calculated in GaBi, and subsequently exported to DATSUPI. The export process in the GaBi/DATSUPI interface structures GaBi data according to the requirements in the PCR. In this step it is also possible to translate the GaBi results to available languages (in the case limited to Norwegian and English). The result is a stand-alone DATSUPI database, which can be created specifically for each furniture manufacturer. The combined use of GaBi and DATSUPI is a trade-off that has the benefit of allowing the LCA data to be accessible in GaBi for expert use (e.g. for other LCA studies such as in-depth analyses in the furniture industry) and in DATSUPI the furniture manufacturers have an accessible front end that does not require extensive LCA knowledge. The cost of the trade-off is the maintenance of the GaBi/DATSUPI interface.

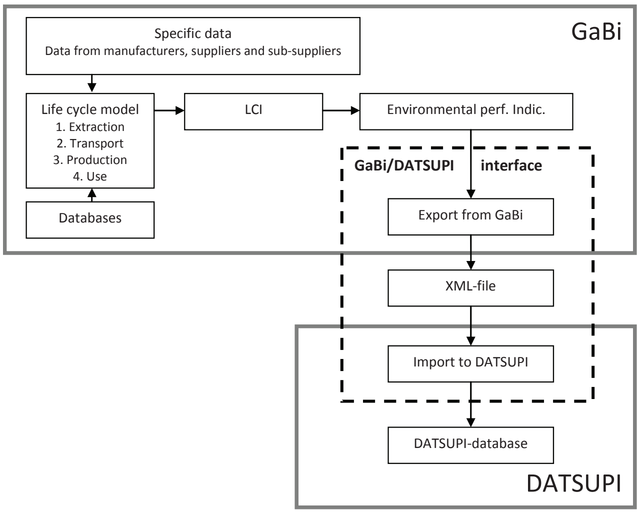


Figure 9: GaBi-DATSUPI data flow

The GaBi-DATSUPI interface made it possible to maintain the modular approach for LCA data that had been developed in the first phase. The DATSUPI user interface continued the modular approach, allowing the user to create and re-use modules within DATSUPI. This met the first requirement for a streamlined user interface. The second requirement was the possibility to update the DATSUPI database without having to re-create all user content (e.g. modules and product models). Using an XML database instead of Excel made it possible for the user to install an updated database, without affecting previous user input. The GaBi-DATSUPI interface made this possible, using unique identification codes for all data elements (e.g. LCA modules, input flows and output flows). The use of identification codes also made it possible to meet the third requirement, creating customised databases. User access to data in DATSUPI could be limited where necessary, for example for specific suppliers and manufacturing processes. A positive consequence of this approach was simplified maintenance of the GaBi database, eliminating the need for exporting a specific database for each company.

5.3.3 Third phase: simplified verification

It is possible for an EPD to cover multiple product variants, provided that the variation in any impact category is below a defined threshold; for example, in the Norwegian EPD system this threshold is defined individually for each product group, but is maximum 5 % (EPD Norway, 2009b). The number of EPDs that a company needs to cover its product range can therefore be significantly lower than the number of actual products. It is difficult to estimate in advance the exact number of EPDs that need to be created by a company, as this requires a priori knowledge of the environmental performance of all the products. Testing of the prototype revealed that some furniture manufacturers had the need to produce a high number of EPDs (> 50 per year) mainly because of variation in product size (variations in back length, seating, etc.) that fell outside the 5 % threshold defined in the PCR (EPD Norway, 2008). The reason for the large variation stemmed from business models focused on providing products with a high degree of customisation. This variation came without a correspondingly high variation in resource material types, component types or production processes. There was a perceived redundancy in the verification process, as the same underlying data were verified multiple times. From this status came a need for a simplified verification system for the furniture manufacturer. The following two requirements were formulated, based on the stated need: 1) the new verification system must be less time and resource consuming for the furniture manufacturer (ease of use) and 2) the level of trust in the verification result and in the EPD must not be compromised (maintain credibility).

In the case study there were two options to verify an EPD. The first is the original verification procedure of EPD Norway, which requires the EPD and an underlying LCA report to be verified by an independent third party as described above. The second verification option is systems based, as described below, where the results must be independently verified within the company. The company can select which verification system to use.

The solution required going beyond the individual manufacturer. The LCA database (Skaar et al., 2009) was verified independently through EPD Norway, and procedures were developed for creating an EPD based on combining input from the manufacturer (material bills, supplier overview, production time per product, etc.) with the verified database. These procedures were integrated in the manufacturer's existing environmental management system, and were thus verified through the ISO 14001 certification. This solution was intended to be applicable to business-to-business communication; it was not developed for business-to-consumer communication (EPD Norway, 2009b).

The systems based verification option described above was implemented in one of the case companies and integrated with the company's ISO 14001 environmental management system. The DATSUPI database is the first systems based verification alternative in the Norwegian EPD system, with a test period of three years (the DATSUPI database was verified for the period between 2009 and 2012) (EPD Norway, 2012). In the ensuing period an unknown (but higher than before) number of EPDs were produced by the company using the systems based verification option. The results indicate that the DATSUPI solution moved in a positive direction related to the two requirements to the verification system (ease of use and maintained credibility).

5.3.4 Fourth phase: human health aspects from indoor emissions

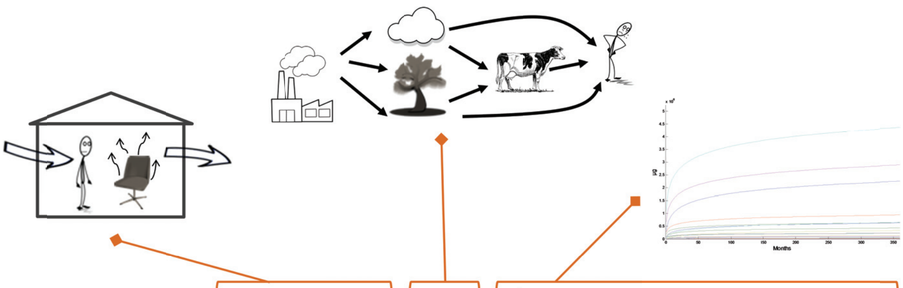
The last of the three needs that were identified at the end of the first phase in the case study was the need to address social aspects, with the requirement being to enable the furniture manufacturers to document and communicate on aspects relating to chemical use. A literature review was performed to identify the state-of-the-art of accountability approaches for value chains (see Paper 4). This literature review identified two gaps concerning how CSR is dealt with in the value chain. The first gap is that there are no reporting approaches that combine social and environmental aspects. The second gap is that there are no reporting approaches that combine the product life cycle (processes) and the extended supply chain (organisation). Addressing these two gaps was the starting point for the fourth phase in the case study.

Social aspects in the value chain have in the case study been delimited to 1) chemical use in the production phase and 2) product emissions in the use phase, as described in Section 5.3 and in Paper 5 and Paper 6. These aspects can be classified under two of the seven core subjects defined in the ISO 26000 on CSR (as presented in Section 3.3): the aspect of labour practices (re: production phase) and the aspect of consumer issues (re: use phase). The aspects were chosen because they are the most salient aspects, both as stated by the case companies and in reflection of the demands put forth by customers and authorities. The need can be expressed as providing furniture that is safe to produce and safe to use. Multiple types of requirements relating to this need have been formulated by authorities and NGOs. Examples of these are the EU's REACH directive (European Commission, 2012b) for regulating and controlling chemical substances, Greenguard certification scheme (Greenguard, 2010) with threshold requirements for emission levels and the Nordic Swan labelling scheme (Nordic Ecolabelling, 2011) with similar thresholds in a broader set of criteria that also address other aspects such as quality and safety.

In the production phase a risk based approach has been chosen. It is based on first identifying all chemicals used in the production (including intermediaries) and collecting material safety data sheets (MSDS) for these. The next step is to document the amount used in the production and the amount found in the final product of each chemical. This gives an overview of all chemicals, but does not distinguish between different hazard levels. Information from the MSDS is therefore used to classify the chemicals in five classes, from CRM (carcinogenic, reprotoxic and mutagenic) to no classification required. Each class is assigned a weighting, based on severity (1000, 100, 10, 0.1, 0). This makes it possible to calculate an inherent health factor, which is a sum of all the amounts of chemical used multiplied with the weighting factor for each chemical (Abrahamsen et al., 2008).

A drawback of the approach described above is that it does not take into account how each organisation deals with chemicals. Using the weighting factors presented above, an organisation that requires the use of protective equipment will end up with the same inherent health factor as an organisation where workers are exposed to the chemicals. In order to address this issue, it is possible to introduce a new set of weighting factors that take into account efforts to reduce exposure (e.g. if an occupational hygienist is used regularly to improve working conditions). Thus the inherent health factor becomes the sum of all the amounts of chemical used multiplied with the weighting factor for each chemical and multiplied with a factor representing the reduced risk when protective measures are taken.

In the use phase an impact based approach has been used, where the impact on human health from product emissions is calculated and integrated into an LCA (see Paper 6). This approach, as illustrated in Figure 10, is based on calculating the impact on human health (measured in comparable toxic units, CTU). This is done by first measuring emissions from the product (first term in the equation in Figure 10), then linking the emissions with a fate, exposure and effect model (second term in the equation in Figure 10) and finally modelling these over the product life time (third term in the equation in Figure 10). The model is described below, and further information can be found in Paper 6.



$$CTU_{h,indoor} = \frac{IR * h}{V * m * 24 * k_{ex}} * EF_{inh} * \int_0^t \frac{E_0}{[(1 + (n-1) * k * t * E_0^{n-1}]^{1/(n-1)}}$$

Figure 10: Illustration of calculating the toxicity [CTU] of indoor emissions using USEtox effect factors (EF)

The basis for the model is USEtox, a multimedia and multi-compartment environmental fate, exposure and effect model developed by UNEP/SETAC. It is based on a scientific consensus principle (Rosenbaum et al., 2008), and is here adapted to estimate the potential impact on human health from indoor and outdoor emissions in the life cycle. Following the recommendations of Hellweg et al. (2009) a homogeneously mixed one-box model is used to model indoor exposure. The model is connected to the surroundings through ventilation. The model is further simplified by disregarding any concentrations of substances in the ingoing ventilation air, limiting the focus to the additional impact of the studied product. Inhalation is assumed to be the most significant exposure pathway, thus excluding dermal contact and ingestion from the assessment (Meijer et al., 2005). For outdoor emissions characterisation factors from USEtox have been used directly and for indoor emissions effect factors from USEtox are used in conjunction with an intake fraction (*iF*) for indoor exposure. The relationship between CTU, characterisation factors and effect factors for exposure is:

$$CTU = m_{tot} * iF * EF = m_{tot} * CF \qquad (1)$$

$$CTU = m * CF \qquad (2)$$

where *CTU* is the impact on human health measured in comparative toxic units [cases/kg emitted] (Rosenbaum et al., 2008), *m* is the mass of the emitted substance, *iF* is the intake fraction, *EF* is the human health effect factor the specific substance (specified for inhalation, ingestion, dermal contact, as well as cases of cancer and non-cancer, see the USEtox model for more information (USEtox, 2011)) and the *CF*s are the indoor or outdoor characterisation factors of the substances. For outdoor exposure the intake fraction is taken directly from the USEtox model, whereas for indoor exposure it is calculated as:

$$iF = \frac{IR}{V*mx*k_{ex}} * N = \frac{IR*h}{V*m*24*k_{ex}} \qquad (3)$$

where *IR* is inhalation rate (m^3/hour), *h* is exposure time (hours/day), *V* is room volume (m^3), *mx* is the mixing factor (how well the air is mixed in the room, not to be confused with *m* for mass), k_{ex} is the air exchange rate per hour and *N* is the number of people exposed. Assuming one person per product eliminates *N* from the equation.

The solutions presented above partially address only two of the seven core subjects identified in the ISO 26000. Although these were the two most salient subjects for the furniture industry and met their stated needs and requirements, this shows that much remains when addressing social aspects in the furniture value chain.

5.4 Performance indicators in the case study

In the case study a number of performance indicators have been selected for quantifying environmental and social aspects. The environmental performance indicators have been developed to meet the requirements in the ISO 14205, whereas the social performance indicators have been developed based on other criteria (e.g. LCA, labelling criteria, IAQ, OHS). Classification and calculation of performance related to chemicals use the concept of an inherent health factor. The inherent health factor is described in Paper 5 , and is further described in Abrahamsen (2008). An overview of performance indicators used in the case study is provided in Table 6. The left side of the table shows an overview of the indicators, sorted by three categories, and the right hand side of the table provides a brief explanation for each indicator. The first category is performance indicators which are in accordance with the ISO 14025 (ISO, 2006d) and the PCR for seating (EPD Norway, 2008, see Appendix 7 for full text), and are intended to be included in an EPD. The second category is performance indicators related to social aspects in the product life cycle. The third category is performance indicators that are related to the extended value chain. The majority are operational performance indicators (as described in Section 4.3), except for indicators concerning the inherent health factor which are management performance indicators.

Table 6: Operational and managerial performance indicators used in the case study

Indicators (per functional unit)	Explanation
Indicators according to ISO 14025 requirements	
Resource use	Material consumption in kg, energy consumption in MJ/kWh
Emissions	Emissions to air, land, water in kg
Wastes	Types of waste, e.g. hazardous
Environmental impacts	Selected impact categories, e.g. global warming potential, acidification potential
Indicators used in the case study, product life cycle	
Classification of health impacts	Six classification levels, from class 1 (CRM: carcinogenic, mutagenic and reprotoxic substances) to class 6 (no classification due to health effects)
Classification of environmental impacts, chemicals	Six classification levels, from class 1 (persistent, bio-accumulative and toxic substances) to class 6 (no classification due to environmental effects)
Inherent health factor	Composite indicator: For each classification level a weight is determined (0 for class 6, 1000 for class 1). For each class the amount used is multiplied with the weight (*in the case study limited to producer and supplier, where information could be found)*
Indoor emissions, inventory	Volatile organic emission rates, measured at 6, 24, 48, 72, 96, 168 and 672 hours
Indoor emissions, human health impact	Human health impact calculated based on emissions inventory and characterisation factors
Indicators used in the case study, extended supply chain	
Weighting factor, inherent health factor	Adjustment factors based on the level based on occupational hygiene conditions, from 1 (no reported protective measures) to 0.001 (documented fully acceptable working conditions)
Intake fraction	Factor based on exposure time and ventilation conditions (*in the case study a generic Nordic value has been calculated*)

6 Measuring, managing and communicating CSR in value chains through product declarations

6.1 Accountability in the value chain

In the previous chapter the case study and research results were introduced. In response to the needs of selected Norwegian furniture manufacturers quantified performance indicators were used to measure and communicate on selected environmental and social aspects in the value chains. The organisation's active management of such aspects was implicitly present in the third phase only, through the development of verification solution that was integrated within a certified environmental management system. A systematic approach is required when a continual improvement perspective is employed to deal with environmental and social aspects in the value chain. This research clarifies the need for an integrated approach to measuring, managing and communicating CSR aspects. The existence of this need is supported by findings in the literature review in Paper 4, where gaps in current reporting practices were identified and proposed to be closed by developing the EPD into a CSR product declaration. This requires two changes to the current EPD. The first is to expand the scope of the EPD to also include social aspects. The second is to include environmental and social aspects related to the extended supply chain.

In response to this need, a framework has been developed that an organisation can use to measure, manage and communicate on CSR performance in their value chain. The framework uses CSR product declarations to provide quantified information to stakeholders. The framework is based on a recently proposed framework for environmental assessment of fish food production systems developed by Fet, Schau and Haskins (Fet et al., 2010; Schau, 2012), which has been selected because it is based on four elements that are relevant in this research: product reporting, value chains, systems engineering and assessment of the environmental impact. This qualifies it as a potential candidate for further development into a CSR management and communication framework. The final framework is constructed as a response to research question 3, with the purpose of:

- Providing quantified and verified information to stakeholders
- Addressing social and environmental aspects in the value chain (in the case study: human health and environment)

Two further criteria have been added, based on the results and experiences of the case study. The framework must:

- Be based on life cycle and systems thinking
- Focus on continual improvement

The framework is presented in Section 6.2 below, and the potential use of the framework is exemplified using the case study results in Section 6.3.

6.2 Framework for management and communication of environmental and social aspects of products in the value chain (MCES framework)

Figure 11 shows the framework for Management and Communication of Environmental and Social aspects of products (MCES framework). The Fet, Schau and Haskins framework (Fet et al., 2010; Schau, 2012) has been generalised by expanding the scope from fish food products to product systems in general and broadened by expanding the scope to include social aspects. This modification allows environmental and social aspects of both the product life cycle and the extended supply chain to be analysed within the same system boundaries, potentially preventing problem-shifting between environmental and social aspects (provided that all relevant impacts are included in the system). Embedded in the MCES framework is a feedback loop through management review. This feedback loop links the MCES framework to the PDCA cycle of continual improvement, e.g. as recommended by ISO 14001. It thus becomes a management framework that can be integrated in a company's management system.

The starting point when applying the MCES framework is activity A, which establishes an initial overview of the product system, its stakeholders and processes. This provides a foundation for the iterative work sequence performed through activities B-J. This work sequence is integrated with the six step systems engineering process shown in Figure 11. An outcome of the MCES framework is the creation of a CSR product declaration, which in turn provides input to an organisation's management system and can be communicated to stakeholders.

The focus here is on the development of framework that can meet the four criteria presented in Section 6.1. The extent of resources needed in each step in the MCES framework is highly dependent on the status of existing reporting systems, if they are sufficient, if they must be improved upon, or, when no systems exists, created. When a product reporting system is used in an accountability perspective, there should be established a CSR product declaration programme with a programme operator. This can help ensure development of trustworthy verification procedures for PCR documents and for CSR product declarations. A programme operator can also ensure that relevant stakeholders have been consulted in the development of the PCR document (Christiansen et al., 2006), potentially increasing the legitimacy of the CSR product declaration. The PCR will provide guidance and requirements for the application of the MCES framework. If there is no relevant PCR in existence, one must be developed. The elements of the MCES framework are described below.

Getting started

The first activity (A) is to get an overview of the product system. This includes an initial mapping of stakeholders, processes and products. Although the product system description is created as the first activity, the iterative nature of the framework ensures that once the product system description has been created it can be updated, for example to reflect new information found in subsequent stakeholder analyses.

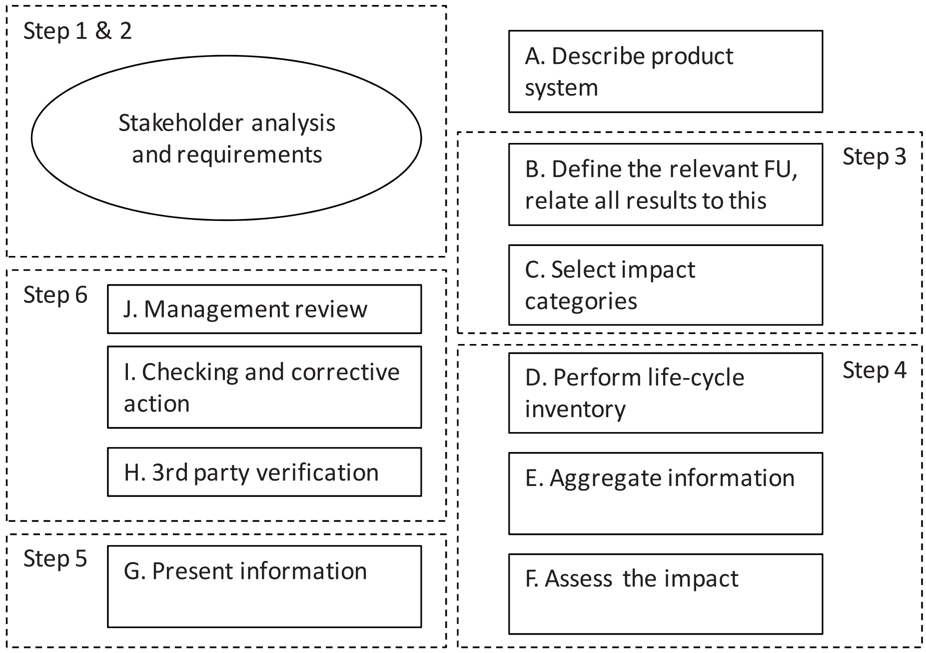


Figure 11: Framework for management and communication of environmental and social aspects of products (MCES framework) (modified from Fet et al. (2010)).

<u>Step 1 and 2: Identify needs and define requirements</u>

Perform a stakeholder analysis in order to find the information needs related to the environmental and social impacts of the product system. Based on the results of the stakeholder analysis, the requirements are formulated. The overall requirement is, by definition, to establish rules and requirements that assist in providing information on the CSR performance of a product. For environmental aspects, a number of requirements are specified in detail in the PCR document, if a relevant one exists. As the PCR document is required to go through a public hearing process, key stakeholders have the opportunity to be involved in the development of the requirements. For social aspects there is currently no similar procedure. This means that unless a PCR that addresses both the environmental and social aspects exists and can be adopted, a PCR must be developed (e.g. by an organisation or a group of organisations).

<u>Step 3: Specify performance</u>

The next step is to specify the performance criteria that the CSR product declaration must meet. It is here important to clarify that at this stage it is the performance of the declaration itself that is of interest, not the performance of the product system. The focus is here on the quality of the reported information, not on the environmental and social performance of the product. The declaration is intended to provide information in a decision making process, and it is in this process the performance of the product system is evaluated (for example to identify hot spots in the life cycle or when comparing products). Specifying performance criteria for the CSR product declaration includes defining the functional unit, selecting environmental and social impact categories and selecting verification method.

Step 4: Analyse and optimise

A goal when analysing and optimising the CSR product declaration system is to ensure comparability between products within the same product category. This requires that a relevant functional unit (FU) is defined in step 3. In step 4, aggregation and allocation methods are selected in order to relate the Life Cycle Inventory (LCI) data to the functional unit, including Life Cycle Impact Assessment (LCIA) methods. The selection of FU and LCIA methods is an iterative process, which can be refined, updated or replaced when there are scientific reasons for doing so. At the level of the individual CSR product declaration, the activities in this step focus on the LCI and LCIA phases in the analysis. At the level of the reporting system the activities in this step focus on the PCR document system, in particular in the creation and revision of these.

Step 5: Design, solve and improve

The purpose of this step is to define the content and format of the CSR product declaration, an activity that is most relevant when the PCR documents are created and revised. This step concerns both the information that is to be presented in the PCR (e.g. indicators, system boundary figures) and how the information should be presented (e.g. format, layout and graphics). The solution must meet the requirements and performance criteria found in earlier steps, as well as requirements in the ISO 14025 for environmental aspects.

Step 6: Verify, test and report

The final step is to ensure that the PCR document is approved by the programme operator and that the CSR product declaration is verified by an independent third party. Furthermore, it must be ensured that the CSR product declaration is communicated in a proper manner to relevant stakeholders, in particular that it is not presented as a quantification of the total environmental and social impact, but as a quantification of a selected number of environmental and social impacts.

The MCES framework links to the PDCA cycle of environmental management systems through the activities I and J, which is an extension of the Schau, Fet and Haskins framework. The borders of step 6 are proximate to each of the 5 previous steps, intended to reinforce the presence of a feedback loop. The framework can be applied in a short-term and in a long-term continual improvement perspective (as discussed in Section 4.2.2), depending on the activities undertaken in step 6. An example of a short-term cycle within an organisation is product improvement, where the goal is to improve the CSR performance of a single product (activities D-I). An example of a long-term cycle going beyond the organisation is improvement of the product declaration system itself, for example expanding the scope based on step 1 and 2 (i.e. taking into account additional needs stemming from a product's social impacts) or step 3 (i.e. specifying additional impact categories). Improvement in a long-term perspective also means improvement of the PCR document.

As the MCES framework addresses both social and environmental aspects (steps 1-3) and includes a PDCA cycle, it goes beyond the stated scope of the ISO 14025 (ISO, 2006d) and thereby also the scope of an EPD programme. However, the existence of a product reporting programme according to ISO 14025 and with relevant PCR documents can simplify the application of the framework when creating a product declaration, as a starting point is provided for defining the system boundaries, selecting environmental impact categories and verification options. It is recommended that the environmental assessment is performed in accordance with the ISO 14040 and ISO 14044 standards. For social aspects it is recommended to contribute to consensus building approaches, for example using the UNEP/SETAC guidelines, but it should be noted that there is not yet scientific consensus in this area.

6.3 MCES as a tool for visualisation: exploring the case study phases

The MCES framework can be used as a visualisation tool in the planning stage or in retrospect to analyse previous activities. Here the MCES framework is used to visualise the four phases in the case study. Figure 12-Figure 15 show the four phases, identifying which SE steps and work process activities have been undertaken (within the coloured outline) and which aspects have been addressed (green for activities that address environmental aspects, yellow for activities that address social aspects).

Figure 12 is a visual representation of the first stage in the case study. The figure shows that although the activities A-H were included in the framework, a number of gaps could be identified from the visual information in the figure. The first was that it did not address social aspects, the second that activities I and J were not included and the third was missing feedback loops from SE step 6 to steps 3, 4 and 5. Furthermore, the feedback from the furniture manufacturers (i.e. users of the software) showed that there was a need to further improve the software solution that was developed in the first phase, as described in Section 5.3. The next three phases in the case study were devoted to solving these issues, with Figure 13 illustrating the development of a streamlined user interface in phase II. It shows how the streamlining was focused on two activities: life cycle inventory (D) and presenting information (G). In response to this DATSUPI was developed.

In phase III of the case study, shown in Figure 14, a new verification solution was developed. In this phase, step 6 focused on integrating DATSUPI with a continual improvement-based management system. This links the activities in steps 1, 2, 3, 4 and 5 to the process of verifying the ISO 14001 procedures. This solution both improved the verification process in activity I, as well as ensuring the development of procedures that made it possible to integrate DATSUPI within an environmental management system.

Phase IV, as shown in Figure 15, expanded beyond environmental aspects in two life cycle stages. It now included chemicals in the production stage and product emission in the use stage. It should be noted that the social aspects that are included in the case study cover a very limited number of aspects that could potentially be addressed in a study concerning social aspects (e.g. social indicators in the GRI framework (GRI, 2010) or the non-environmental core subjects of ISO 26000 (ISO, 2010)).

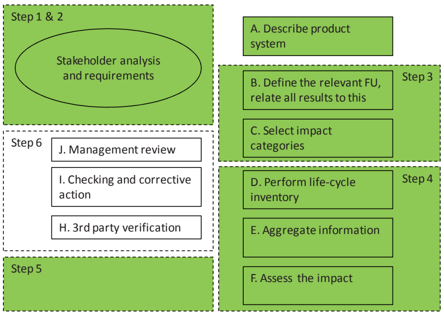


Figure 12: Phase I, environmental aspects

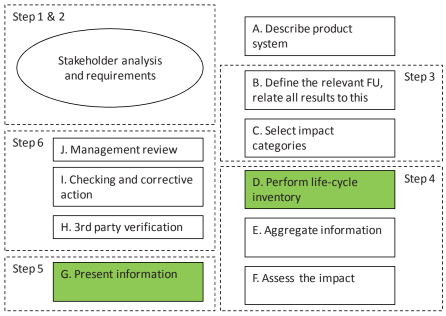


Figure 13: Phase II, streamlined interface

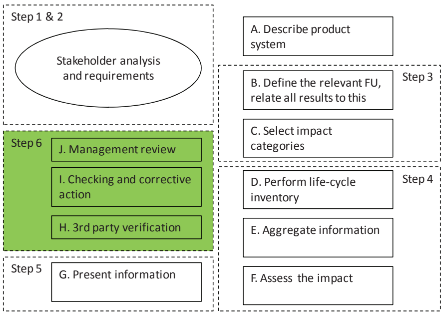


Figure 14: Phase III, streamlined verification

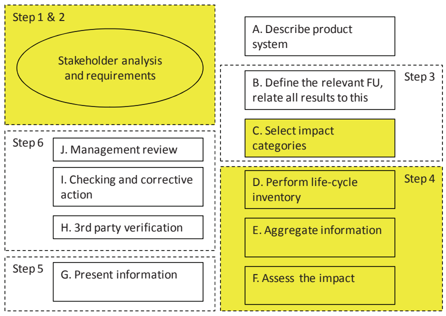


Figure 15: Phase IV, social aspects

This shows how the MCES framework can be used as a visualisation tool to describe the transitions through the four phases in the case study, and to identify options for further development. It should be mentioned that there are limitations when relying on a visual approach, namely loss of content depth in the description of each activity. As an example, when comparing step 1 & 2 in the first and last phase, the actual stakeholders are not identified in the framework. In the first phase, a stakeholder consultation round was required when creating the PCR according to ISO 14025, whereas the last activity is based on the need as perceived by the furniture manufacturers and identified through literature review.

Each step and each work process in the MCES framework must therefore be analysed in detail, starting with the visual representation. Further activities might include using a gap analysis between an ideal state (e.g. compared to state-of-the-art in each element) and the actual or planned state.

7 Discussion

The purpose of this thesis is to address CSR performance of products, starting with identifying and measuring CSR aspects and continuing with managing and communicating on these aspects to key stakeholders. From the literature review and case study a framework for dealing with CSR performance in the value chain has been developed (MCES), which was the main goal at the outset. The MCES framework is based on integrating product declarations within a continual improvement-based management system. The discussion below first addresses the three research questions formulated to support the main goal, followed by a discussion of the case study results and the advantages and limitations of the MCES framework. Finally reflections on the research process follow.

7.1 Research questions

The results in light of the theme of each of the three research questions are discussed below. The first section (7.1.1) deals with research question 1 based on both the literature review presented in Paper 4 and the case study results (as presented in Chapter 5). The next section (7.1.2) deals with research question 2 based on the results of the literature review and section 7.1.3 deals with research question 3 based on the case study results and the MCES framework (Chapter 6).

7.1.1 Research question 1: Measuring and communicating environmental and social product performance

Figure 4 in Section 4.2.3 shows how environmental and social aspects can be represented as either flows or attributes of processes in the product life cycle, where attributes can in turn be dependent on the individual organisations in the extended supply chain. When these flows and attributes are quantified, this is the starting point for measuring product performance in environmental and social aspects. The literature review and the case study results show that while there are allocation and aggregation methods available for environmental flows (i.e. allocation and aggregation of operational performance indicators for environmental aspects), there is no consensus on allocation and aggregation of indicators relating to 1) management performance indicators for environmental aspects, 2) operational performance indicators for social aspects and 3) management performance indicators for social aspects. The nature of the three challenges related to allocation and aggregation means that it is not possible to develop characterisation factors based on scientific methods. A value based approach must therefore be used. In the case study a proposed solution is to develop weighting factors, which have the inherent weakness that they are not objective. This means that they are not compatible with the existing ISO 14025; either the standard must be updated (to include social aspects and to include subjective indicators based on weighting) or the product declaration must be developed outside the ISO 14025 system. Aggregation challenges can be found where ever there are incommensurable indicators, for example in deciding how chemical use in the production phase should be compared to emissions in the use phase.

The indicators concerning chemicals in the case study concern the reduction of negative impact on human health from exposure to hazardous substances. This issue is dealt with at three levels in the case study. The first is the inventory level (chemical use in the production phase and emission rates in the use phase), the second is the organisational efforts to reduce chemical exposure (weighting factor reflecting the occupational hygiene standards) and the third is including the impact on human health from indoor emissions in the existing LCA impact category of human health. These three can only be aggregated to a single impact category through the use of weighting factors. In other words, the results show that the current practice for identifying and measuring CSR performance in the value chain is lacking methods for aggregation and allocation, methods that should preferably be scientific and at least consensus based. This is also the status for attempts to develop social LCA (Benoît-Norris et al., 2011; Benoît et al., 2010). The case study has attempted to expand product declaration to include social aspects. In practice, this has been delimited to fitting social aspects within an LCA framework. The experience in the case study showed that a CSR product declaration inherits the limitations of LCA, and is therefore dependent on further development of social LCA.

The case companies' practices for communicating on product performance were varied at the start of the case study. None of the companies had developed environmental or social labelling of their products (e.g. Nordic Swan, EU Eco-label). One of the companies had EPDs for the majority of the product portfolio, one had for a small segment of the product portfolio, whereas the last two had not produced any EPDs. Communication on the environmental and social performance of the products in these latter instances was limited to answering direct questions from customer (e.g. through pre-qualification questionnaires in the contract market). By the close of the case study period, all companies had developed EPDs for the majority of products in two of the four selected product categories (seating, and beds and mattresses). It should be noted that one company created its EPDs without using the DATSUPI software and databases, as this company had outsourced these activities to an external research partner.

At the end of the case study period, two of the companies had created EPDs for a the majority of their product portfolios. The Norwegian furniture industry has furthermore proposed a joint industry effort to build on the experiences of the DATSUPI in order to expand to all interested companies in the furniture industry. An observation in this regard is that the labelling schemes have successfully penetrated both the consumer and contract markets, whereas the use of EPDs is still mainly limited to the contract market. This may be due to the volume of information included in an EPD, which is not easily interpreted by consumers (Christiansen et al., 2006). Developing a CSR product declaration will further complicate the picture, as additional aspects and indicators are included. This suggests that there is a need to simplify the use of product declarations in decision processes, especially for non-expert decision makers. Such a simplification should not be done at the expense of transparency and credibility; instead it should be either done outside the product declaration (e.g. through comparison tools) or in addition to the information that is already in the product declaration. This is in contrast to single criteria declarations, which can be based on the selection of a single impact category (e.g. water footprints (Berger and Finkbeiner, 2010) and carbon footprints (Finkbeiner, 2009)) or a weighting of several impact categories (Engels et al., 2010). These may provide information that it is easier to base a decision on, but a challenge for the first approach is that it limits the scope of the study and a challenge for the second approach is that it limits the transparency of the reported information.

7.1.2 Research question 2: CSR in the value chain and the role of product declarations

The literature review presented in Paper 4 showed that there are two gaps between CSR concerns in the value chain and what is currently addressed in product declarations. The first gap that there were no approaches that looked both at the product life cycle and the extended supply chain. The second gap is that there is no combined environmental and social approach at the level of product reporting (i.e. declarations, not labels). Both these gaps are related to challenges of quantifying and measuring flows and attributes that go beyond environmental performance of the product life cycle, which were discussed in the previous section.

In the case study a number of product declarations have been developed that provide quantified information on selected environmental and social aspects of a product. As CSR is here defined as taking responsibility for the environmental and social impacts of the organisation and its value chain, the question becomes: can developing product declarations be considered as taking responsibility beyond legal requirements? The Norwegian environmental information act (MD, 2001) states that the public has a right to know of all significant environmental impacts of a product. Strictly interpreted this means that an EPD including only environmental aspects cannot be considered as a CSR activity as it merely fulfils existing legal requirements. Rather, not being able to produce an EPD (or similar information) when faced with demand for environmental information can be considered a breach of the environmental information act. There is no evidence that this strict legal interpretation is applied in practice, not even by the authorities. This is similar to the situation for corporate reporting; only 10 of the 100 largest Norwegian firms were found in a 2006 survey to be in strict compliance with legal requirements for corporate reporting on environmental aspects (Vormedal and Ruud, 2009). A possible viewpoint is that product declarations go beyond what is legally enforced, and can therefore be considered as a CSR activity.

If the underlying EPD is not seen as a CSR activity, the question is if expanding the content to go beyond environmental impacts can be considered as going beyond legal requirements. In the case study two (partially overlapping) extensions have been attempted: including impacts on human health (social) and including attributes (e.g. on the management systems in the extended supply chain). This interpretation means that creating product declarations can be considered as CSR if they go beyond environmental impacts.

Furthermore, if creating a product declaration is not regarded as a CSR activity, then contributing to continual improvement can be regarded as a CSR activity. There is a requirement in the Norwegian internal control regulation to continual improvement (AD, 1996), but this is related to the individual organisation and not the value chain. Product declarations that deal with the whole value chain (product life cycle and extended supply chain) can thus be considered as going beyond legal requirements. Continual improvement can be either of the product itself (the product life cycle), of the product declaration (e.g. improving the systems and standards used), or of the organisation and its value chain (the extended supply chain).

The challenge of identifying if product declarations can be considered as CSR supports the notion of a Nordic variant of CSR where there is "little room for moving «beyond compliance»" (Carson et al., 2011: 4). This leaves two options for what can be considered as CSR activities in a Nordic context, in regards to product declarations. The first is participating in activities of continual improvement (e.g. through using the MCES framework or similar approaches) and the second is through increased accountability. Accountability includes verification of information that is communicated, and disclosing transparently on limitations; for example, limitations related to indirect rebound effects, which are typically not considered in an environmental LCA (Arvesen et al., 2011; Huppes and Ishikawa, 2009) or in a social LCA (Jørgensen et al., 2010). In other words, responsibility extends to not giving the wrong impression of the product declaration as showing the whole picture or being the only vantage point of the value chain (Hancock, 2007). The challenge of measuring CSR thus links to the challenge of measuring sustainability.

7.1.3 Research question 3: Measuring, managing and communicating CSR product performance

The MCES framework has been developed as a response to research questions 2 and 3, addressing the topics of measuring, aggregating, managing and communicating CSR performance in the value chain, through the use of product declarations. It is based on combining the procedural tool of Systems Engineering with the analytical tool of LCA.

Dealing with environmental aspects in the MCES framework is based on an integrated use of existing standards: ISO 14001 for environmental management, ISO 14020 and ISO 14025 for environmental product declarations, ISO 14040 and ISO 14044 for life cycle assessment. Used together these cover the continual improvement aspect in the MCES framework (using the PDCA cycle) and the environmental impact of the product life cycle. But these standards do not address the organisations in the value chain, i.e. the extended supply chain.

In the case study the extended supply chain has not been included for environmental aspects, due to resource constraints. Developing performance indicators for the extended supply chain (e.g. the presence of environmental certifications and environmental management systems) face the same difficulties as when developing performance indicators for social aspects, namely those of aggregation and allocation. Life Cycle Attribute Assessment (Andrews et al., 2009; Norris, 2006) is an approach that may be used to develop such performance indicators, and can potentially provide a bridge between social and environmental aspects LCA. These types of indicators may be used to evaluate which management systems and certification schemes are the most effective to reduce environmental impact in the value chain.

For social aspects there are no similar standards to the ISO 14000 series available. Attempts have been made to integrate social aspects in LCA (e.g. as discussed in Section 4.2.3), but there is no consensus on which indicators to use (Benoît-Norris et al., 2011). Furthermore, stakeholder dialogue is a central aspect in CSR (Morsing and Schultz, 2006). In a product declaration system this is covered mainly through involving stakeholders in the development or revision of PCR documents. PCR documents are revised infrequently (typically a 3-5 year period of validity), thus limiting the mandatory stakeholder dialogue cycles.

7.2 Systems Engineering and the MCES framework: Advantages and limitations

As described in Section 6.2, Systems Engineering is used in the MCES framework to systematically address the needs and requirements of all relevant stakeholders. Systems and sub-systems are central issues in SE, fitting well with the modular approach used in the case study. Recognising that the MCES framework has only been applied in hindsight, the perceived main advantages and limitations of the MCES framework are discussed here.

The advantages of the MCES framework are related to the strengths of the underlying tools. LCA is capable of addressing a broad range of environmental aspects in the life cycle, and SE is capable of capturing and dealing comprehensively with the needs and requirements of a broad range of stakeholders. Linking these strengths to the PDCA cycle within a company's environmental management system and setting objectives and targets, makes MCES a framework for continual improvement in a systematic manner. In this respect, the strength of the MCES framework is drawn from the strength of the underlying tools.

As the strength of the underlying tools becomes the strength of the MCES framework, this is also true for the limitations. Especially dealing with social aspects shows the Achilles heel of the product declaration approach. There is a multitude of potential aspects that may be addressed, and there is a lack of agreed upon methods for dealing with these. Defining needs and requirements will in this context become an impossible task for a single company. Developing comparable CSR product declarations using the MCES framework is therefore dependent on scientific consensus on inventory analysis, methods for allocation and aggregation as well as social impact assessment. Making decisions when faced with a large amount of information is also a challenge. This challenge may be addressed using multi-criteria decision analysis (MCDA) (Myllyviita et al., 2012). Furthermore, there is a lack of agreed upon background databases that can be used to create comparable CSR product declarations (this is especially a challenge for social aspects, but is also relevant for environmental aspects in regions lacking state of the art databases). However, the lack of scientific consensus should not be an obstacle to using the MCES framework to develop CSR product declarations, it can instead be seen as supporting Bebbington's call for "methodological pluralism coupled with stakeholder participation" (Bebbington, 2009: 189) when accounting for SD performance.

Another positive contribution of the MCES framework is in identifying opportunities for collaboration, as it is connected to external stakeholders through steps 1 and 2 (stakeholder analysis and requirements). Developing rules and requirements for CSR product declarations is a daunting task, which calls for a collaborative approach. The case study has shown how a number of companies can work together to develop a product declaration system, based on principles of comparability and verification.

An aspect that has not been addressed here is the potential further development in the Norwegian furniture industry. Two of the case companies are located in what has been called a Norwegian furniture cluster in Møre and Romsdal (Amdam et al., 2007), and it is likely that the results may be transferable to these cluster companies with some additional effort. The question is how this will affect the case companies. Will they have first mover advantage or will the subsequent companies enjoy the fruits of previous labour?

7.3 Reflections on the research process

Corporate Social Responsibility (CSR) has been selected as the theoretical concept within which to explore the foundation and extent of business responsibility. This choice is based on the conviction that business has a moral obligation to include environmental and social concerns in their decision making, which translates to a specific definition of CSR.

The social aspects were initially defined in broader terms, but through the case study it was clear that these are the aspects that are the least developed and most challenging to develop. The research framework was refined organically through iterations in the case study, for example leading to Occupational Health and Safety (OHS) being limited to Indoor Air Quality (IAQ). Within the resource constraints of the case study and the exploratory nature of the research, this delimitation can be justified in light of the results. The results include both identifying further research needs (i.e. developing allocation and aggregation methods that can be used to measure, manage and communicate on CSR product performance) and to the integration of indoor emissions into the LCA methodology.

In retrospect it appears that Systems Engineering was a fruitful tool to use in the case study, but that the full potential of SE was likely not utilised. In particular the linkage between requirements and verification/testing could have been stronger, for example through establishing success criteria that looked beyond the research project and into an eventual proliferation stage. It is reasonable to assume that the new requirements introduced in the second stage on streamlining the EPD creation process could have been avoided or simplified.

8 Conclusion

8.1 Findings and contributions

There are three main contributions from this thesis to the scientific discourse, presented in this and subsequent paragraphs. The first contribution is the findings of the literature review of management, certification and reporting approaches. Here two gaps in current reporting practices were identified: there are no globally recognised reporting approaches that deal with both the processes and the organisations that together constitute the value chain, and that there are no reporting approaches that deal with both social and environmental aspects in the value chain. The literature review showed that there is a need for such an integrated approach. The identification of these gaps is thus the first contribution.

The second contribution is a Life Cycle Impact Assessment (LCIA) method that integrates impact on human health from product emissions in the use phase into a Life Cycle Assessment (LCA). This contribution comes from the exploratory case study that was performed in the Norwegian furniture industry, based on contributing to and learning from a number of research projects in the period between 2005 and 2010. The case study was divided into four phases. Each phase was analysed through a systems engineering perspective, from identifying stakeholders, needs and requirements to developing and testing solutions. Practical results include the DATSUPI software (for documenting environmental and social performance of products), a verified LCA database (for creating EPDs), and procedures for creating and verifying EPDs within an environmental management system. Social performance in the case study is delimited to chemical use in the production phase and product emissions in the use phase.

The third contribution of the research is the MCES framework, which integrates product reporting with a PDCA management system through the use of Systems Engineering (SE). Building on the ISO 14001 and the ISO 14025 standards, the framework demonstrates how product reporting can be a central activity in continual development of environmental and social performance. This improvement can be for a product, for an organisation and for a value chain. The framework is an extension of an earlier framework for product reporting, and is quantitative and based on the use of performance indicators. The results of the case study show the main challenge when applying such a framework with the intention of including social aspects is that of finding indicators that can be allocated and aggregated throughout the value chain and still be meaningful. This supports the initial findings of the literature review. Without scientific consensus on indicators and aggregation methods, transparency in reporting is critical in a CSR context.

When discussing CSR product declarations it should again be stated that there is a fundamental difference between the concepts of efficient and effective. The efficiency indicators that are included in a product declaration can for example only tell us how much environmental or social impact the product has, but they cannot tell us if we are doing the right process in the first place. For increased efficiency only the product itself needs to improve, negative indirect effects (e.g. rebound effects) are ignored. For increased effectiveness the improvement must be considered for the system as a whole, including indirect effects. For this reason it is recommended to keep in mind that continual improvement should consider the product, the value chain (the product life cycle and the extended supply chain), and the product declaration system itself.

8.2 Further research

This research has identified several areas where there is need for further research. These can be distinguished between those that are relevant for the case study and those that are relevant for the methods and tools used in the case study. Further research that could make product declarations a more useful tool, are:

- Testing and verifying implementation of the MCES framework
- Organisational perspectives on implementing the MCES framework
- Developing a common background database
- Simplification of information in product declarations
- Study of the effectiveness of EPDs, i.e. do they transfer understanding and result in economic benefits for the products

The background database in DATSUPI was developed for the four case companies, but should be developed at a higher level. For comparability between furniture manufacturers, this database should be further developed to include the entire furniture industry. For comparability at a higher level where furniture will be sub-system (e.g. between buildings or lifestyles), a background database should be developed to be used by all participants in an EPD programme (e.g. the EPD Norway system).

Further research is also needed at the level of tools, in particular with regards to social aspects. This research should be anchored in the scientific, with consensus building and proliferation as sub-goals.

- Developing allocation and aggregation methods: for social aspects and for the extended supply chain
- Social impact assessment: going beyond the inventory level
- Databases including social aspects

Research in these areas has a global relevance, and the answers can contribute to avoiding shifting our problems to other countries and other generations.

9 References

Abrahamsen, U., Jørgensen, R. B., Svendsen, K., Svanes, E., & Fossdal, S. (2008). *Environmental Product Declarations (EPDs) as a tool for documentation/information on chemicals and toxicity in the value chains of products – a pre-study for EPD-Norge.*: NTNU.

AD. (1996). *Forskrift om systematisk helse-, miljø- og sikkerhetsarbeid i virksomheter (Internkontrollforskriften)*: Norwegian Ministry of Labour.

Amdam, R. P., Lunnan, R., & Ramanauskas, R. (2007). FDI and the Transformation from Industry to Service Society in Emerging Economies: A Lithuanian - Nordic Perspective. *Engineering Economics*(1).

Ammenberg, J., & Sundin, E. (2005). Products in environmental management systems: the role of auditors. *Journal of Cleaner Production, 13*(4), 417-431.

Andrews, E., Lesage, P., Benoît, C., Parent, J., Norris, G., & Revéret, J.-P. (2009). Life Cycle Attribute Assessment - Case Study of Quebec Greenhouse Tomatoes. *Journal of Industrial Ecology, 13*(4), 565-578.

Arvesen, A., Bright, R. M., & Hertwich, E. G. (2011). Considering only first-order effects? How simplifications lead to unrealistic technology optimism in climate change mitigation. *Energy Policy, 39*(11), 7448-7454.

Asbjørnsen, O. A. (1992). *Systems Engineering, Principles and Practice*: Skarpodd.

Azapagic, A. (2003). Systems Approach to Corporate Sustainability: A General Management Framework. *Process Safety and Environmental Protection, 81*(5), 303-316.

Azapagic, A., & Perdan, S. (2000). Indicators of Sustainable Development for Industry: A General Framework. *Process Safety and Environmental Protection, 78*(4), 243-261.

Bakan, J. (2004). *The corporation the pathological pursuit of profit and power*. New York: Free Press.

Balkau, F., & Sonnemann, G. (2010). Managing sustainability performance through the value-chain. *Corporate Governance, 10*(1), 46-58.

Bauman, H., & Tillman, A.-M. (2004). *The hitch hiker's guide to LCA : an orientation in life cycle assessment methodology and application*. Lund, Sweden: Studentlitteratur.

Baumgartner, R. J. (2011). Critical perspectives of sustainable development research and practice. *Journal of Cleaner Production, 19*(8), 783-786.

Bebbington, J. (2009). Measuring sustainable development performance: Possibilities and issues. *Accounting Forum, 33*(3), 189-193.

Benoît-Norris, C., Vickery-Niederman, G., Valdivia, S., Franze, J., Traverso, M., Ciroth, A., et al. (2011). Introducing the UNEP/SETAC methodological sheets for subcategories of social LCA. *International Journal of Life Cycle Assessment, 16*(7), 682-690.

Benoît, C., Norris, G., Valdivia, S., Ciroth, A., Moberg, A., Bos, U., et al. (2010). The guidelines for social life cycle assessment of products: just in time! *The International Journal of Life Cycle Assessment, 15*(2), 156-163.

Berger, M., & Finkbeiner, M. (2010). Water Footprinting: How to Address Water Use in Life Cycle Assessment? *Sustainability, 2*(4), 919-944.

Bernardo, M., Casadesus, M., Karapetrovic, S., & Heras, I. (2009). How integrated are environmental, quality and other standardized management systems? An empirical study. *Journal of Cleaner Production, 17*(8), 742-750.

Bertalanffy, L. v. (1968). *General system theory foundations, development, applications*. New York: George Braziller.

Blanchard, B. S., & Fabrycky, W. J. (1990). *Systems engineering and analysis* (2nd ed.). Englewood Cliffs, N.J.: Prentice-Hall.

Blindheim, B.-T., & Langhelle, O. (2010). A reinterpretation of the principles of CSR: a pragmatic approach. *Corporate Social Responsibility and Environmental Management, 17*(2), 107-117.

Booth, A., Sutton, A., & Papaioannou, D. (2011). *Systematic approaches to a successful literature review*. London: Sage.

Brannen, J. (2008). The Practice of a Mixed Methods Research Strategy: Personal, Professional and Project Considerations. In M. M. Bergman (Ed.), *Advances in Mixed Methods Research*. London: SAGE Publications Ltd.

Brouwer, M. A. C., & van Koppen, C. S. A. (2008). The soul of the machine: continual improvement in ISO 14001. *Journal of Cleaner Production, 16*(4), 450.

Bryman, A. (2008). *Social research methods* (3rd ed.). Oxford: Oxford University Press.

Burgherr, P., Hirschberg, S., Brukmajster, D., & Hampel, J. (2005). *Survey of criteria and indicators*. Stuttgart. (NEEDS

Carson, S. G., Fet, A. M., & Skaar, C. (2011). A Nordic Perspective of Corporate Social Responsibility (CSR). *Etikk i praksis, 2011*(1).

Chertow, M. (2000). The IPAT Equation and Its Variants. *Journal of Industrial Ecology, 4*(4), 13-29.

Christiansen, K., Wesnæs, M., & Weidema, B. P. (2006). *Consumer demands on Type III environmental declarations*: 2.0 LCA consultants.

Christopher, M. (2005). *Logistics and supply chain management : creating value-adding networks* (3rd ed.). London: Prentice Hall/Financial Times.

Curkovic, S., & Sroufe, R. (2011). Using ISO 14001 to promote a sustainable supply chain strategy. *Business Strategy and the Environment, 20*(2), 71-93.

Curran, M. (2008). Life-Cycle Assessment. In S. E. Jorgensen & B. Fath (Eds.), *Encyclopedia of Ecology* (pp. 2168-2174). Oxford: Academic Press.

Dahlsrud, A. (2006). How corporate social responsibility is defined: an analysis of 37 definitions. *Corporate Social Responsibility and Environmental Management, 15*(1), 1-13.

Dando, N., & Swift, T. (2003). Transparency and Assurance Minding the Credibility Gap. *Journal of Business Ethics, 44*(2), 195-200.

Dokka, T. H. (2000). *Modelling of indoor air quality in residential and commercial buildings*. Trondheim: Department of Industrial Economics and Industrial Management.

Duchin, F., Levine, S. H., Editors in, C., xA, Sven Erik, J., & Brian, F. (2008). Industrial Ecology. In *Encyclopedia of Ecology* (pp. 1968-1975). Oxford: Academic Press.

Ehrenfeld, J. R. (2005). The roots of sustainability. *Mit Sloan Management Review, 46*(2), 23-25.

Engels, S. V., Hansmann, R., & Scholz, R. W. (2010). Toward a Sustainability Label for Food Products: An Analysis of Experts' and Consumers' Acceptance. *Ecology of Food and Nutrition, 49*(1), 30-60.

EPD Norway. (2005). *Product Category Rules for preparing an Environmental Product Declaration (EPD) for Product Group Beds and Mattresses* (No. NPCR004). Oslo: EPD Norway,.

EPD Norway. (2006). *Product Category Rules for preparing an Environmental Product Declaration (EPD) for Product Group Upholstery textiles* (No. NPCR006). Oslo: EPD Norway,.

EPD Norway. (2008). *Product Category Rules for preparing an Environmental Product Declaration (EPD) for Product Group Seating Solution* (No. NPCR003). Oslo: EPD Norway,.

EPD Norway. (2009a). *Product Category Rules for preparing an Environmental Product Declaration (EPD) for Product Group Table* (No. NPCR005). Oslo: EPD Norway,.

EPD Norway. (2009b). *Retningslinjer for Næringslivets Stiftelse for Miljødeklarasjoner (EPD-Norge)*

EPD Norway. (2012). Referat fra EPD-Norge sitt årsmøte 1. september 201 (minutes from EPD Norway annual meeting 2010). Retrieved 9 March, 2012, from http://www.epd-norge.no/article.php?articleID=1097&categoryID=188

Erickson, P. A. (1996). *Practical guide to occupational health and safety*. San Diego: Academic Press.

European Commission. (2011). *A renewed EU strategy 2011-14 for Corporate Social Responsibility*. Brussels: European Commission.

European Commission. (2012a). EMAS. Retrieved 30 January, 2012, from http://ec.europa.eu/environment/emas/index_en.htm

European Commission. (2012b). REACH. Retrieved 12 March, 2012, from http://ec.europa.eu/environment/chemicals/reach/reach_intro.htm

FAD. (1999). *Lov om offentlige anskaffelser (Public Procurement Act)*: Ministry of Government Administration, Reform and Church Affairs.

Faße, A., Grote, U., & Winter, E. (2009). *Value Chain Analysis: Methodologies in the Context of Environment and Trade Research* (No. Discussion Paper No. 429): Gottfried Leibniz University of Hannover.

Fet, A. M. (1997). *Systems engineering methods and environmental life cycle performance within ship industry*. Trondheim: NTNU.

Fet, A. M. (2002). Systems Engineering, Environmental Management tools and their application in Industrial Ecology. Trondheim: Programme for Industrial Ecology.

Fet, A. M., Michelsen, O., & Skaar, C. (2009a). Creating environmental product declarations (EPDs) - case study in the Norwegian furniture industry. In *Life Cycle Assessment applications: Results from COST Action 530* (pp. 238-244): AENOR.

Fet, A. M., Schau, E. M., & Haskins, C. (2010). A framework for environmental analyses of fish food production systems based on systems engineering principles. *Systems Engineering, 13*(2), 109-118.

Fet, A. M., Skjellum, M., Håskjold, J., Aaser, C. P., & Emilsen, M. (2009b). *Hovedrapport DATSUPI*. Trondheim: NTNU.

Fet, A. M., & Skaar, C. (2010). Bedriftenes produktansvar – en casestudie fra norsk møbelindustri. In *Bedrifters samfunnsansvar - Hvordan forene ønsker og praksis?* (pp. 337-368): Tapir Akademisk Forlag.

Fet, A. M., Skaar, C., Dahlsrud, A., Michelsen, O., & Riddervold, B. (2005a). *Praktisk faktisk. "Frittgående" forskere i møbelbransjen gir resultater.* Paper presented at the P2005.

Fet, A. M., Skaar, C., & Helbostad, A. G. (2005b). *Øko-effektivitet og verdikjeder i dagligvarebransjen* (No. IØT 01/05). Trondheim: NTNU.

Fet, A. M., Skaar, C., & Michelsen, O. (2009c). Product category rules (PCR) and environmental product declarations (EPDs). In *Life Cycle Assessment applications: Results from COST Action 530* (pp. 73-80): AENOR.

Fet, A. M., Skaar, C., & Michelsen, O. (2009d). Product category rules and environmental product declarations as tools to promote sustainable products: experiences from a case study of furniture production. *Clean Technologies and Environmental Policy, 11*(2), 201-207.

Fet, A. M., Skaar, C., & Riddervold, B. (2006). *Miljødatabase og miljødeklarasjoner for møbler* (No. 1/2006). Trondheim: NTNU.

Fink, A. (2010). *Conducting Research Literature Reviews. From the Internet to Paper* (3rd ed.). Thousand Oaks, Calif.: Sage.

Finkbeiner, M. (2009). Carbon footprinting - opportunities and threats. *The International Journal of Life Cycle Assessment, 14*(2), 91-94.

Finkbeiner, M., Inaba, A., Tan, R. B. H., Christiansen, K., & Kluppel, H. J. (2006). The new international standards for life cycle assessment: ISO 14040 and ISO 14044. *International Journal of Life Cycle Assessment, 11*(2), 80-85.

Finkbeiner, M., Saur, K., Eyerer, P., Matsuno, Y., & Inaba, A. (1999). Analysis of the potential for a comprehensive approach towards LCA and EMS in Japan. *The International Journal of Life Cycle Assessment, 4*(3), 127-132.

Finnveden, G., Hauschild, M. Z., Ekvall, T., Guinee, J., Heijungs, R., Hellweg, S., et al. (2009). Recent developments in Life Cycle Assessment. *Journal of Environmental Management, 91*(1), 1-21.

Finster, M., Eagan, P., & Hussey, D. (2002). Linking Industrial Ecology with Business Strategy. *Journal of Industrial Ecology, 5*(3).

Flyvbjerg, B. (2006). Five misunderstandings about case-study research. *Qualitative Inquiry, 12*(2), 219-245.

Foran, B., Lenzen, M., Dey, C., & Bilek, M. (2005). Integrating sustainable chain management with triple bottom line accounting. *Ecological Economics, 52*(2), 143-157.

Freeman, R. E. (2010). *Stakeholder theory the state of the art*. Cambridge: Cambridge University Press.

Friedman, M. (1970). The Social Responsibility of Business is to Increase its Profits. *The New York Times Magazine*.

Frosch, R. A. (1992). Industrial ecology: a philosophical introduction. *Proceedings of the National Academy of Sciences, 89*(3), 800-803.

Garriga, E., & Melé, D. N. (2004). Corporate Social Responsibility theories: Mapping the territory. *Journal of Business Ethics, 53*(1-2), 51-71.

Gasparatos, A., El-Haram, M., & Horner, M. (2009). The argument against a reductionist approach for measuring sustainable development performance and the need for methodological pluralism. *Accounting Forum, 33*(3), 245-256.

Glavic, P., & Lukman, R. (2007). Review of sustainability terms and their definitions. *Journal of Cleaner Production, 15*(18), 1875-1885.

Graedel, T. E., & Allenby, B. R. (1995). *Industrial ecology*. Englewood Cliffs, N.J.: Prentice Hall.

Greenguard. (2010). *Greenguard Indoor Air Quality (IAQ) Standard for Building Materials, Finishes and Furnishings*: Greenguard Environmental Institute.

GRI. (2010). Global Reporting Initiative. Retrieved 20 January, 2010, from http://www.globalreporting.org

Grießhammer, R., Benoît, C., Dreyer, L. C., Flysjö, A., Manhart, A., Mazijn, B., et al. (2006). *Feasability Study: Integration of social aspects into LCA*. Freiburg: UNEP-SETAC.

Guinee, J., Heijungs, R., Kleijn, R., Voet, E. v. d., Koning, A. d., Oers, L. v., et al. (2006). Human and Ecological Life Cycle Tools for the Integrated Assessment of Systems (HELIAS). *The International Journal of Life Cycle Assessment, 11*(0), 19-28.

Hahn, T., Figge, F., Pinkse, J., & Preuss, L. (2010). Trade-offs in corporate sustainability: you can't have your cake and eat it. *Business Strategy and the Environment, 19*(4), 217-229.

Haigh, N., & Griffiths, A. (2009). The natural environment as a primary stakeholder: the case of climate change. *Business Strategy and the Environment, 18*(6), 347-359.

Halme, M., Roome, N., & Dobers, P. (2009). Corporate responsibility: Reflections on context and consequences. *Scandinavian Journal of Management, 25*(1), 1-9.

Hancock, G. R. (2007). Models for illuminating things otherwise unseen: Co-editor's introduction. *Contemporary Educational Psychology, 32*(1), 4-7.

Haskins, C. (2006). *Systems Engineering Handbook*: International Council on Systems Engineering (INCOSE).

Haskins, C. (2008). *Systems engineering analyzed, synthesized, and applied to sustainable industrial park development.* Fakultet for samfunnsvitenskap og teknologiledelse.

Hawken, P., Lovins, A. B., & Lovins, L. H. (1999). *Natural capitalism creating the next industrial revolution* (1st ed.). Boston: Little.

Hellweg, S., Demou, E., Bruzzi, R., Meijer, A., Rosenbaum, R. K., Huijbregts, M. A. J., et al. (2009). Integrating Human Indoor Air Pollutant Exposure within Life Cycle Impact Assessment. *Environmental Science & Technology, 43*(6), 1670-1679.

Hertwich, E. G. (2005). Consumption and the Rebound Effect: An Industrial Ecology Perspective. *Journal of Industrial Ecology, 9*(1-2), 85-98.

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

Huppes, G., & Ishikawa, M. (2009). Eco-efficiency guiding micro-level actions towards sustainability: Ten basic steps for analysis. *Ecological Economics, 68*(6), 1687-1700.

Hutchins, M. J., & Sutherland, J. W. (2008). An exploration of measures of social sustainability and their application to supply chain decisions. *Journal of Cleaner Production, 16*(15), 1688-1698.

IIGSS. (2001). *Some Streams of Systemic Thought*: International Institute for General Systems Studies.

Institute for Environment and Sustainability. (2010). *ILCD handbook: General guide for Life Cycle Assessment*: European Commission.

ISO. (1999a). *Environmental labels and declarations -- Self-declared environmental claims (Type II environmental labelling) (ISO 14021:1999)*. Geneva: International Organization for Standardization.

ISO. (1999b). *Environmental labels and declarations -- Type I environmental labelling -- Principles and procedures (ISO 14024:1999)*. Geneva: International Organization for Standardization.

ISO. (2000a). *Environmental labels and declarations -- General principles (ISO 14020:2000)*. Geneva: International Organization for Standardization.

ISO. (2000b). *Environmental management - Environmental performance evaluation (ISO 14031:2000)*: International Organization for Standardization.

ISO. (2004a). *Environmental management systems -- Requirements with guidance for use (ISO 14001:2004)*. Geneva: International Organization for Standardization.

ISO. (2004b). *Miljøstyringssystemer : spesifikasjon med veiledning : (ISO 14001:2004)* (2. utg. ed.). Oslo: Standard Norge.

ISO. (2006a). *Environmental labels and declarations -- Type III environmental declarations -- Principles and procedures (ISO 14025:2006)*. Geneva: International Organization for Standardization.

ISO. (2006b). *Environmental management - Life cycle assessment - Principles and framework (ISO 14040:2006)*: International Organization for Standardization.

ISO. (2006c). *Environmental management - Life cycle assessment - Requirements and guidelines (ISO 14044:2006)*: International Organization for Standardization.

ISO. (2006d). *Miljømerker og deklarasjoner, miljødeklarasjoner type III, prinsipper og prosedyrer (ISO 14025:2006)*. Oslo: Standard Norge.

ISO. (2008a). *The integrated use of management system standards*. Geneva: International Organization for Standardization.

ISO. (2008b). *ISO 15288:2008 Systems and software engineering - System life cycle processes ISO/IEC, IEEE* (2nd rev. ed.). Geneve: International Organization for Standardization.

ISO. (2010). *Guidance on social responsibility (ISO 26000:2010)*. Geneva: International Organization for Standardization.

ISO. (2011). *High level structure and identical text for management system standards and common core management system terms and definitions (ISO/DGuide 83, draft)*. Geneva: International Organization for Standardization.

ISO. (2012). *Environmental management - Eco-efficiency assessment of product systems - Principles, requirements and guidelines (ISO FDIS 14045)*. Geneva: International Organization for Standardization.

Jørgensen, A., Finkbeiner, M., Jørgensen, M., & Hauschild, M. (2010). Defining the baseline in social life cycle assessment. *The International Journal of Life Cycle Assessment, 15*(4), 376-384.

Jørgensen, A., Hauschild, M., Jørgensen, M., & Wangel, A. (2009). Relevance and feasibility of social life cycle assessment from a company perspective. *The International Journal of Life Cycle Assessment, 14*(3), 204-214.

Jørgensen, A., Le Bocq, A., Nazarkina, L., & Hauschild, M. (2008). Methodologies for social life cycle assessment. *The International Journal of Life Cycle Assessment, 13*(2), 96-103.

Jørgensen, T. H. (2008). Towards more sustainable management systems: through life cycle management and integration. *Journal of Cleaner Production, 16*(10), 1071-1080.

Jørgensen, T. H., Remmen, A., & Mellado, M. D. (2006). Integrated management systems - three different levels of integration. *Journal of Cleaner Production, 14*(8), 713-722.

Kaplinsky, R., & Morris, M. (2000). *A Handbook for Value Chain Research*: Institute of Development Studies, University of Sussex.

Kicherer, A., Schaltegger, S., Tschochohei, H., & Pozo, B. F. (2007). Eco-efficiency - Combining life cycle assessment and life cycle costs via normalization. *International Journal of Life Cycle Assessment, 12*(7), 537-543.

Kissinger, M., & Rees, W. E. (2009). Assessing Sustainability in a Globalizing World Toward Interregional Industrial Ecology. *Journal of Industrial Ecology, 13*(3), 357-360.

Kjellén, U. (2000). *Prevention of accidents through experience feedback*. London: Taylor & Francis.

Klein, N. (2000). *No Logo*. London: HarperCollins.

Kolk, A. (2008). Sustainability, accountability and corporate governance: exploring multinationals' reporting practices. *Business Strategy and the Environment, 17*(1), 1-15.

Korhonen, J. (2002). Two Paths to Industrial Ecology: Applying the Product-based and Geographical Approaches. *Journal of Environmental Planning and Management, 45*, 39-57.

Korhonen, J. (2003). Should we measure corporate social responsibility? *Corporate Social Responsibility and Environmental Management, 10*(1), 25-39.

Korhonen, J. (2004). Industrial ecology in the strategic sustainable development model: strategic applications of industrial ecology. *Journal of Cleaner Production, 12*(8-10), 809-823.

Korten, D. C. (1995). *When corporations rule the world*. London: Earthscan.

Kossiakoff, A., Sweet, W. N., Seymour, S. J., & Biemer, S. M. (2011). *Systems Engineering: Principles and Practice* (2nd ed.). New Jersey: Wiley.

Lamberton, G. (2005). Sustainability accounting--a brief history and conceptual framework. *Accounting Forum, 29*(1), 7-26.

Lewandowska, A., Matuszak-Flejszman, A., Joachimiak, K., & Ciroth, A. (2011). Environmental life cycle assessment (LCA) as a tool for identification and assessment of environmental aspects in environmental management systems (EMS). Part 2: case studies. *Journal of Life Cycle Assessment, online first*.

Lifset, R. (2008). The Quantitative and the Qualitative in Industrial Ecology. *Journal of Industrial Ecology, 12*(2), 133-135.

Lin, Y. (2007). The Tao of Systems. Retrieved 20 September, 2011, from http://isss.org/projects/ancient_systems_thinking_in_china

Mandel, T. (1997). History and Systems. An inquiry at the beginning of history. Retrieved 20 September, 2011

MD. (2001). *Lov om rett til miljøinformasjon og deltakelse i offentlige beslutningsprosesser av betydning for miljøet (miljøinformasjonsloven)*: Norwegian Ministry of the Environment.

Meadows, D. H., & Club of Rome. (1972). *The Limits to growth a report for the Club of Rome's project on the predicament of mankind*. London: Earth Island Ltd.

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.

Michelsen, O. (2006). *Eco-efficiency in extended supply chains methodological development with regulatory and organizational implications elektronisk ressurs*. Trondheim: Norwegian University of Science and Technology, Faculty of Social Sciences and Technology Management.

Missimer, M., Robèrt, K.-H., Broman, G., & Sverdrup, H. (2010). Exploring the possibility of a systematic and generic approach to social sustainability. *Journal of Cleaner Production, 18*(10-11), 1107-1112.

Mitchell, C. A., Carew, A. L., & Clift, R. (2004). The Role of the Professional Engineer and Scientist in Sustainable Development. In A. Azapagic, S. Perdan & R. Clift (Eds.), *Sustainable Development in Practice* (pp. 29-56). Chichester: John Wiley & Sons, Ltd.

Mitchell, R. K., Agle, B. R., & Wood, D. J. (1997). Toward a theory of stakeholder identification and salience: Defining the principle of who and what really counts. *Academy of Management Review, 22*(4), 853-886.

Moneva, J. M., Archel, P., & Correa, C. (2006). GRI and the camouflaging of corporate unsustainability. *Accounting Forum, 30*(2), 121-137.

Montero, M. J., Araque, R. A., & Rey, J. M. (2009). Occupational health and safety in the framework of corporate social responsibility. *Safety Science, 47*(10), 1440-1445.

Morsing, M., & Schultz, M. (2006). Corporate social responsibility communication: stakeholder information, response and involvement strategies. *Business Ethics: A European Review, 15*(4), 323-338.

Mueller, M., dos Santos, V. G., & Seuring, S. (2009). The Contribution of Environmental and Social Standards Towards Ensuring Legitimacy in Supply Chain Governance. *Journal of Business Ethics, 89*(4), 509-523.

Myllyviita, T., Holma, A., Antikainen, R., Lähtinen, K., & Leskinen, P. (2012). Assessing environmental impacts of biomass production chains â€" application of life cycle assessment (LCA) and multi-criteria decision analysis (MCDA). *Journal of Cleaner Production, 29-30*, 238-245.

Möller, A., & Schaltegger, S. (2005). The sustainability balanced scorecard as a framework for eco-efficiency analysis. *Journal of Industrial Ecology, 9*(4), 73-83.

Nawrocka, D., Brorson, T., & Lindhqvist, T. (2009). ISO 14001 in environmental supply chain practices. *Journal of Cleaner Production, 17*(16), 1435-1443.

Nordic Ecolabelling. (2011). *Nordic Ecolabelling of Furniture and fitments*. Oslo

Norges forskningsråd. (2004). *Bedriftenes samfunnsansvar. Forslag til et nytt forskningsprogram*. Oslo: Norges forskningsråd.

Norris, G. (2001). Integrating life cycle cost analysis and LCA. *The International Journal of Life Cycle Assessment, 6*(2), 118-120.

Norris, G. (2006). Social Impacts in Product Life Cycles - Towards Life Cycle Attribute Assessment. *The International Journal of Life Cycle Assessment, 11*(0), 97-104.

Ny, H., MacDonald, J. P., Broman, G., Yamamoto, R., & Robért, K.-H. (2006). Sustainability Constraints as System Boundaries: An Approach to Making Life-Cycle Management Strategic. *Journal of Industrial Ecology, 10*(1-2), 61-77.

O'Connor, M., & Spangenberg, J. H. (2008). A methodology for CSR reporting: assuring a representative diversity of indicators across stakeholders, scales, sites and performance issues. *Journal of Cleaner Production, 16*(13), 1399-1415.

Parent, J., Cucuzzella, C., & Revéret, J.-P. (2010). Impact assessment in SLCA: sorting the sLCIA methods according to their outcomes. *The International Journal of Life Cycle Assessment, 15*(2), 164-171.

PE International. (2011). GaBi. http://www.gabi-software.com.

Pettersen, J., & Hertwich, E. (2008). Occupational health impacts: offshore crane lifts in life cycle assessment. *The International Journal of Life Cycle Assessment, 13*(5), 440-449.

Pintér, L., Hardi, P., & Bartelmus, P. (2005). *Sustainable Development Indicators: Proposals for the Way Forward*. New York: UNDSD.

Pintér, L., Hardi, P., Martinuzzi, A., & Hall, J. (2012). Bellagio STAMP: Principles for sustainability assessment and measurement. *Ecological Indicators, 17*, 20-28.

Porritt, J. (2005). *Capitalism as if the world matters*. London: Earthscan.

Porter, & Kramer. (2007). Strategy and society: The link between competitive advantage and corporate social responsibility. *Harvard Business Review, 85*(6), 136-137.

Prahalad, C. K. (2005). *The fortune at the bottom of the pyramid*. Upper Saddle River, N.J.: Wharton School Publ.

Rosenbaum, R., Bachmann, T., Gold, L., Huijbregts, M., Jolliet, O., Juraske, R., et al. (2008). USEtox—the UNEP-SETAC toxicity model: recommended characterisation factors for human toxicity and freshwater ecotoxicity in life cycle impact assessment. *The International Journal of Life Cycle Assessment, 13*(7), 532-546.

Schaltegger, S., & Burritt, R. L. (2010). Sustainability accounting for companies: Catchphrase or decision support for business leaders? *Journal of World Business, 45*(4), 375-384.

Schau, E. M. (2012). *Environmental life cycle assessments of fish food products with emphasis on the fish catch process*. Trondheim: Norwegian University of Science and Technology.

Schmidt, I., Meurer, M., Saling, P., Kicherer, A., Reuter, W., & Gensch, C.-O. (2004). SEEbalance®: Managing sustainability of products and processes with the socio-eco-efficiency analysis by BASF. *Greener Management International, 45*.

Sethi, S. P., & Emelianova, O. (2006). A failed strategy of using voluntary codes of conduct by the global mining industry. *Corporate Governance, 6*(3), 226-238.

Seuring, S. (2004). Industrial ecology, life cycles, supply chains: differences and interrelations. *Business Strategy and the Environment, 13*(5), 306-319.

Seuring, S., & Müller, M. (2007). Integrated chain management in Germany - identifying schools of thought based on a literature review. *Journal of Cleaner Production, 15*(7), 699-710.

Skaar, C. (2005). *Norsk Møbeldatabase versjon 01-05*. Trondheim: NTNU.

Skaar, C. (2010). *IGLO-MP2020 WP 02-2010: Aggregation of CSR indicators in a value chain perspective*. Trondheim: NTNU.

Skaar, C., & Fet, A. M. (2006). *Creating industry specific tools for SMEs: Experiences from the Norwegian furniture industry.* Paper presented at the 13th LCA Case Study Symposium, Stuttgart.

Skaar, C., & Fet, A. M. (2011). Accountability in the Value Chain: From Environmental Product Declaration (EPD) to CSR Product Declaration. *Corporate Social Responsibility and Environmental Management*, n/a-n/a.

Skaar, C., & Jørgensen, R. B. (2012). Integrating Human Health Impact from Indoor Emissions into an LCA: A Case Study Evaluating the Significance of the Use Phase. *Journal of Life Cycle Assessment (submitted January 2012)*.

Skaar, C., Lange, R., & Nybakke, E. (2009). *Datasystembeskrivelse - Teknisk rapport for DATSUPI*. Trondheim: NTNU.

Smeets, E., & Weterings, R. (1999). *Environmental indicators : typology and overview*. Copenhagen: European Environment Agency.

Sopha, B. M., Fet, A. M., Keitsch, M. M., & Haskins, C. (2009). Using systems engineering to create a framework for evaluating industrial symbiosis options. *Systems Engineering, 9999*(9999), n/a.

Sparrevik, M., Barton, D. N., Oen, A. M. P., Sehkar, N. U., & Linkov, I. (2011). Use of multicriteria involvement processes to enhance transparency and stakeholder participation at Bergen Harbor, Norway. *Integrated Environmental Assessment and Management, 7*(3), 414-425.

Sproles, N. (2000). Coming to grips with measures of effectiveness. *Systems Engineering, 3*(1), 50-58.

Steinberger, J. K., & Krausmann, F. (2011). Material and Energy Productivity. *Environmental Science & Technology, 45*(4), 1169-1176.

Stellman, J. M. (Ed.). (1998). *Encyclopaedia of occupational health and safety* (4th ed.). Geneva: International Labour Office.

Stevels, A. L. N. (2007). Chapter 5: The Value Chain. In *Adventures in EcoDesign of Electronic Products*.

UN. (2011). Millennium Development Goals. Retrieved 16 September, 2011, from http://www.un.org/millenniumgoals/

UNEP. (2007). *Global environmental outlook (Geo 4) environment for development*. [Nairobi]: UNEP.

UNEP/SETAC. (2009). *Guidelines for Social Life Cycle Assessment of Products*: UNEP/SETAC.

United Nations Conference on Environment and Development. (1992). Agenda 21. Retrieved 13 September, 2011, from http://www.unep.org/Documents.Multilingual/Default.asp?documentid=52

United Nations Conference on Sustainable Development. (2012). Rio+20. Retrieved 14 September, 2011, from http://www.uncsd2012.org/rio20/index.php

USEtox. (2011). USEtox^{TM} model. Retrieved 8 February, 2011, from http://www.usetox.org

Vachon, S., & Mao, Z. (2008). Linking supply chain strength to sustainable development: a country-level analysis. *Journal of Cleaner Production, 16*(15), 1552-1560.

van Tulder, R., van Wijk, J., & Kolk, A. (2009). From Chain Liability to Chain Responsibility. *Journal of Business Ethics, 85*, 399-412.

Victor, D. G. (2006). Recovering sustainable development. *Foreign Affairs, 85*(1), 91-103.

Viddal, M. G., Hermansen, J., & Norberg, O. (1997). *ISO 14000 og EMAS for miljøbevisst ledelse*. Oslo: Tano Aschehoug.

Vogel, D. (2005). *The market for virtue : the potential and limits of corporate social responsibility*. Washington, D.C.: Brookings Institution Press.

Vormedal, I., & Ruud, A. (2009). Sustainability reporting in Norway - an assessment of performance in the context of legal demands and socio-political drivers. *Business Strategy and the Environment, 18*(4), 207-222.

Wackernagel, M., Schulz, N. B., Deumling, D., Linares, A. C., Jenkins, M., Kapos, V., et al. (2002). Tracking the ecological overshoot of the human economy. *Proceedings of the National Academy of Sciences of the United States of America, 99*(14), 9266-9271.

Wang, T., & Graedel, T. (2006). Industrial Ecology. In *Encyclopedia of Environmental Science and Engineering, Fifth Edition, Volumes One and Two*: CRC Press.

WBCSD. (2008). What Gets Measured Gets Done - WBCSD Launches Measuring Impact Framework. Retrieved 19 September, 2011, from http://www.wbcsd.org/plugins/DocSearch/details.asp?type=DocDet&ObjectId=MzA4NTE

WBCSD. (2010). *Business & Development*: World Business Council for Sustainable Development.

Weidema, B. P. (2005). ISO 14044 also Applies to Social LCA. *The International Journal of Life Cycle Assessment, 10*(6), 381-381.

Welford, R., & Starkey, R. (2001). *The Earthscan reader in business and sustainable development*. London Sterling, VA: Earthscan Publications.

Wilkinson, A. M. (1991). *The scientist's handbook for writing papers and dissertations*. Englewood Cliffs, N.J.: Prentice Hall.

World Commission on Environment and Development. (1987). Our common future. Retrieved 13 September, 2011, from http://www.un-documents.net/wced-ocf.htm

Wrisberg, N. (2002). *Analytical tools for environmental design and management in a systems perspective the combined use of analytical tools*. Boston: Kluwer Academic Publishers.

Yin, R. K. (2003). *Case study research design and methods* (3rd ed.). Thousand Oaks, Calif.: Sage.

Zadek, S. (2007). *The civil corporation* (Rev. ed. / with new introductory essay. ed.). London: Earthscan.

Ählström, J., Macquet, M., & Richter, U. (2009). The lack of a critical perspective in environmental management research: distortion in the scientific discourse. *Business Strategy and the Environment, 18*(5), 334-346.

10 Appendices

Appendix 1: Product category rules (PCR) and environmental product declarations (EPDs).

Appendix 2: Creating environmental product declarations (EPDs) – case study in the Norwegian furniture industry.

Appendix 3: Product category rules and environmental product declarations as tools to promote sustainable products: experiences from a case study of furniture production.

Appendix 4: Accountability in the Value Chain: From Environmental Product Declaration (EPD) to CSR Product Declaration.

Appendix 5: Bedriftenes produktansvar – en casestudie fra norsk møbelindustri .

Appendix 6: Integrating Human Health Impact from Indoor Emissions into an LCA: A Case Study Evaluating the Significance of the Use Phase.

Appendix 7: Product-Category Rules (PCR) for preparing an Environmental Product Declaration (EPD) for Product Group Seating solution. NPCR 003 Revised version.

Appendix 1

Product category rules (PCR) and environmental product declarations (EPDs).

COST Action 530

4. Product Category Rules (PCR) and Environmental Product Declarations (EPDs)

Annik Magerholm Fet, Christofer Skaar and Ottar Michelsen

Department of Industrial Economics and Technology Management,
Norwegian University of Science and Technology,
NO-7491 Trondheim, Norway

E-mail: *Annik.Fet@iot.ntnu.no*

4.1. Introduction

To understand the environmental impacts a product can cause, it is not sufficient to know only what happens in the production phase. We must examine the entire lifecycle of the product, from raw material extraction through production, use, recycling, and disposal. Life Cycle Assessment (LCA) is an important tool in this respect, a tool that helps us expand the focus from site to value chain. However, the results of an LCA are in their nature complex, and can be difficult to interpret for non LCA practitioners [Solér 2001, 15]. Additionally, because an LCA can be performed in different ways (depending on the goal and scope of the study) the results are often not directly comparable. Environmental labels and declarations aim to address these issues.

4.2. Theory

There are a multitude of environmental labels and declarations currently in use for products (where products are understood as any goods or service) (ISO 2006a). The International Organization for Standardization (ISO) 14000-series distinguish between three different types of declarations, which all require that life cycle aspects are taken into consideration. These are: Type I programmes, i.e. multiple criteria-based, third party programmes awarding labels claiming overall environmental *preferability* ISO 1999a), Type II programs, i.e., self-declared environmental claims where life cycle considerations are taken into account (ISO 1999b), and Type III programmes (ISO 2006a), which will be discussed here.

The ISO standards for environmental labels and declarations are:

• 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*.

• ISO 21930:2007 *Sustainability in building construction - Environmental declaration of building products*.

To obtain a Type III EPD the requirements are to conduct a Life Cycle Assessment of the product in accordance with the ISO 14040-standards series (ISO 2006bc), and get a third party verification of the LCA and the EPD.

Characteristics of Type III EPDs are that they give objective and quantified environmental information, and that they shall allow comparison of products fulfilling identical functions. It should be noted that there are no environmental performance requirements for a product to get an EPD.

Various names are used for Type III-programs and related product declarations, for example EcoLeaf (Japan Environmental Management Association for Industry (JEMAI), 2002), eco-profile [Tillmann, 1998], environmental declaration of product (Korea Environmental Labelling Association (KELA), 2005), environmental product declaration (EPD) (Swedish Industrial Research Institutes' Initiative (Sirii), 2002) and environmental profile data sheet [Row and Wieler, 2003].

In this chapter Type III EPD is used to refer to a product declaration belonging to any Type III EPD program. For simplicity they are sometimes also referred to as EPD and EPD program.

4.3. Product Category Rules

A product category is a group of products that fulfil the same function. The PCR define the criteria for a specific product category and sets out the requirements that must be met when preparing an EPD. The PCR aims to identify and define rules for the process of creating an EPD, in order to enable a comparison between products. The PCR must therefore:

• Identify the functional and performance characteristics of the product.

• Define the criteria to be used in the LCA study of products belonging to the

category.

• Specify the information that must be reported in the EPD.

A PCR should comply with the requirements of ISO 14025 and the ISO 14040-standards on LCA. In addition, specific technical standards for the relevant product must be fulfilled and information about this shall be listed in the declaration. The development of a PCR-document should follow these steps (ISO 2006):

1. Define product category.

2. Produce appropriate product category background LCA, in order to identify the most significant environmental aspects and impacts of the product category.

3. Specify rules, parameters and requirements for reporting, and how to produce the data required for the product declarations.

The PCR-document must contain the information listed in Table 4.1. Some PCRs were developed before ISO 14025 was completed, therefore the content of some PCRs will vary slightly from this. However, as an approved PCR is normally valid for 3 years, the PCR must eventually be revised according to the structure given in Table 4.1.

Table 4.1. The content of a PCR document (adapted from ISO 2006, 18)

1. General information
2. Definition of product category type
3. LCA-based information
3.1 Definition of functional unit / Declared Unit
3.2 System boundaries
3.3 Description of data
3.4 Criteria for inclusions inputs and outputs, data quality requirements
3.5 Units
4. Inventory analysis
4.1 Data collection and calculation procedures
4.2 Cut off criteria
4.3 Allocation rules
5. Environmental impact categories
6. Parameters and Source of data of the underlying LCA report
7. Other information
7.1 Other product information and parameters to be declared in EPD
7.2 Information on underlying LCA-data
7.3 Other instructions on data gathering for the development of EPDs
7.4 Additional Information (Information from the organisation)
8. Content of the environmental declaration (EPD)
8.1 General information to be declared
8.2 Parameters to be declared: *See Table 3*.

4.4. EPD – format and content

According to point 8 in Table 4.1, the PCR-document shall give instruction to the EPD content. No concrete instructions to the format of the declaration are required. Table 4.2 lists the information to be included in an EPD, and Table 4.3, the parameters to be declared and the suggested impact categories.

Table 4.2. Information to be declared in the EPD (adapted from ISO 2006, 20)

1. Identification and description of the organisation making the declaration.
2. Description of product and product identification.
3. Information on the EPD programme operator.
4. Date of publication and period validity.
5. Data from LCA, LCI or information modules.
6. Additional environmental information.
7. Content declaration (materials and substances in the product).
8. Information on the life cycle stages covered by the EPD.
9. Statement that EPDs from different programmes may not be comparable.
10. Information on where explanatory material may be obtained.

Table 4.3. Parameters to be declared in an EPD, including the recommended impact categories (adapted from ISO 2006, 20). The parameters may be further specified in the PCR

Data from the life cycle inventory
• Use of renewable and non-renewable material resources.
• Use of renewable and non-renewable energy resources.
• Emissions to air, water and soil.
Impact categories
• Climate change.
• Depletion of the stratospheric ozone layer.
• Acidification of land and water sources.
• Eutrophication.
• Formation of tropospheric ozone.
• Depletion of fossil energy resources.
• Depletion of mineral resources.
Other data
• Quantities and types of non-hazardous waste.
• Quantities and types of hazardous waste.

If the EPD does not cover the entire life cycle this shall be clearly stated on the front page of the EPD. Alternative statements can be:

• This declaration covers environmental impacts throughout the product life cycle, from raw material extraction to product disposal.

• This declaration covers environmental impacts from raw material extraction to use and maintenance. The declaration does not cover product disposal, and is therefore not comparable to declarations that cover the entire product life cycle.

• This declaration covers environmental impacts from raw material extraction to production. The declaration does not cover use and maintenance or product disposal, and is therefore not comparable to declarations that cover the entire product life cycle.

• This declaration is a module environmental product declaration. It covers the main production process of the product. Raw material extraction and production, use and maintenance, and disposal are not included.

In addition the EPD can also contain information about service and maintenance, what the owner/user can do to further reduce the environmental impact, information on reuse and recycling as well as guidance on disassembly and waste handling. Information about the environmental management work at the importer, manufacturer or retailer may also be useful to include. All EPDs in a product category shall follow the same format (often a format specified by the EPD programme operator) and include the same data as identified in the PCR provided by the programme operator.

4.5. EPD programmes, review of PCR, and verification of EPD

The programme operator tasks are to prepare, maintain and communicate the programme instructions. Further tasks are to publish the PCRs and EPDs, establish review procedures and monitor related Type III programmes (ISO 2006, 11-12). An additional goal of this work is to stimulate the establishment of a verification system for EPDs. In developing a Type III EPD programme the rules for verification shall be set up in accordance with ISO 14020, ISO 14025 and the ISO 14040-series. The programme operator shall also specify the accreditation requirements for verifiers. A verification procedure shall include the format of verification, its documentation, verification rules and verification results. For verification of EPDs, the verifier shall verify the quality, accuracy and completeness of the data, and in addition, the conformance to the PCR. The verification of LCA data in the EPD shall at minimum conform to the PCR and the ISO 14040 series standards.

Verification systems can vary between different programme operators. Verification of the EPD by an independent third party is required in the Norwegian EPD-system. To ease the verification-process a database or set of databases can be verified, and the verification of the EPDs could therefore be simplified to only cover verification of the in house procedures on how the EPDs are made for the products. Such procedures should be a part of the company’s environmental management system, and should at least cover “procedure for identification of environmental aspects of one's own products”, “procedure for achieving environmental product information at sub-suppliers”, and “procedure for the development of the EPDs using a verified and industry specific database”.

According to ISO 14025 (ISO 2006), it is possible for independent verification of the EPDs to be carried out by the company’s own environmental auditors, provided that the company has an ISO 14001 or EMAS-certified environmental management system and that the certification body has approved the LCA routines as part of the management system.

References:

GEDnet (2005): Global Type III Environmental Product Declarations Network (GEDnet), http://www.gednet.org

ISO (1999a): Environmental labels and declarations — Environmental labelling Type I — Guiding principles and procedures. European Standard EN ISO 14024:1999, Geneva.

ISO (1999b): Environmental labels and declarations — Self-declared environmental claims. European Standard EN ISO 14021:1999, Geneva.

ISO (2006a): Environmental labels and declarations — Environmental labelling Type III —Principles and procedures. EN ISO 14025:2006, Geneva.

ISO (2006b): Environmental management – Life cycle assessment – Principles and framework. EN ISO 14040:2006, Geneva.

ISO (2006c): Environmental management – Life cycle assessment – Requirements and guidelines. EN ISO 14044:2006, Geneva.

Japan Environmental Management Association for Industry (JEMAI): *Introduction of the EcoLeaf environmental Program guidelines*. Japan, 2002.

Korea Environmental Labelling Association (KELA): *EPD Program Introduction*, 2005. http://www.kela.or.kr/english/record/record01_n01.asp

Row J, Wieler C.: *Environmental Labelling for Hydrogen in Canada*. The Pembina Institute, Drayton Valley, 2003.

Solér, C.: *Communication of product related environmental information. User requirement studies of Environmental Product Declaration, EPD, systems*. CPM Report 2001:4, Chalmers, Göteborg, 2001.

Swedish Industrial Research Institutes' Initiative (Sirii): *Guidelines to Type III Environmental Declarations*. Sirii, Sweden, 2002.

Tillmann, A-M: LCA-baserade miljövarudeklarationer typ III. Rapport 1998:4, Chalmers, Göteborg, 1998.

Appendix 2

Creating environmental product declarations (EPDs) – case study in the Norwegian furniture industry.

12. Working group 4 of COST Action 530: Integrated Product Policy

12.4. Creating environmental product declarations (EPDs) – case study in the Norwegian furniture industry

Annik Magerholm Fet; Ottar Michelsen, and Christofer Skar

Department of Industrial Economics and Technology Management
Norwegian University of Science and Technology, NTNU
N 7491 Trondheim, Norway

Email: Annik.Fet@iot.ntnu.no

Abstract

Manufacturing companies are exposed to an increasing demand for declaration of the environmental performance of their products. In particular, small and medium sized enterprises (SMEs) have large challenges in meeting these requirements due to lack of resources and knowledge on environmental issues. To assist the companies in this process, a database on furniture production in Norway is under way. This helps manufacturers to assess the environmental performance of the different materials in their products. This information can be used in environmental product declarations (EPDs). The information about environmental impacts together with cost assessments can also be used to assess the eco-efficiency of the products.

12.4.1. Introduction

New requirements and regulations have increased the pressure on companies to provide information on their products [Michelsen/Fet/Dahlsrud, 2006]. These initiatives have pushed industry to develop environmental product declarations (EPDs) for their products. How industry has dealt with the challenges of developing product categories rules (PCRs) and EPDs is demonstrated by case-studies from the furniture industry in Norway. To enhance the capability of developing EPDs in this industry, a database with specific environmental data for materials used in furniture has been developed. The database is used to conduct the LCA for selected furniture models. Furthermore, the database is the backbone of a data-assistance tool used to design and present the EPDs. "The goal for the spring 2006 was to produce EPDs for our entire product collection. Every week we have to answer questions from authorities in Norway and from abroad and document the content of our products" [Magnar Skjellum at Helland Møbler AS].

12.4.2. The case project

The goal of the project *Databases and product declarations for furniture* [Fet/Skaar/Riddervold, 2006] has been to provide the Norwegian furniture industry with a tool to help companies gather environmental information and document their products according to the requirements of ISO 14025 (ISO 2006). This project is part of a long-term programme in the Norwegian furniture industry with the pilot companies Helland AS, Håg ASA, Ekornes ASA, and Jensen AS. These companies are SMEs or slightly larger. They produce reclining chairs, office chairs, mattresses, and tables for the Norwegian, European and US markets, with an export share ranging from 20% to 90%. Based on earlier projects on cleaner production, waste management programmes, and environmental management systems, a number of LCA projects were performed by the project companies. The LCAs helped them to get information on the most significant environmental aspects of the product and at which point in the life cycle the impacts occur (see Figure 12.11), which materials or parts of the products they stem from, and which impact categories they contribute to. This information helped the companies to establish product related information and develop performance indicators to be used to inform customers, as well as for internal communication and product improvement.

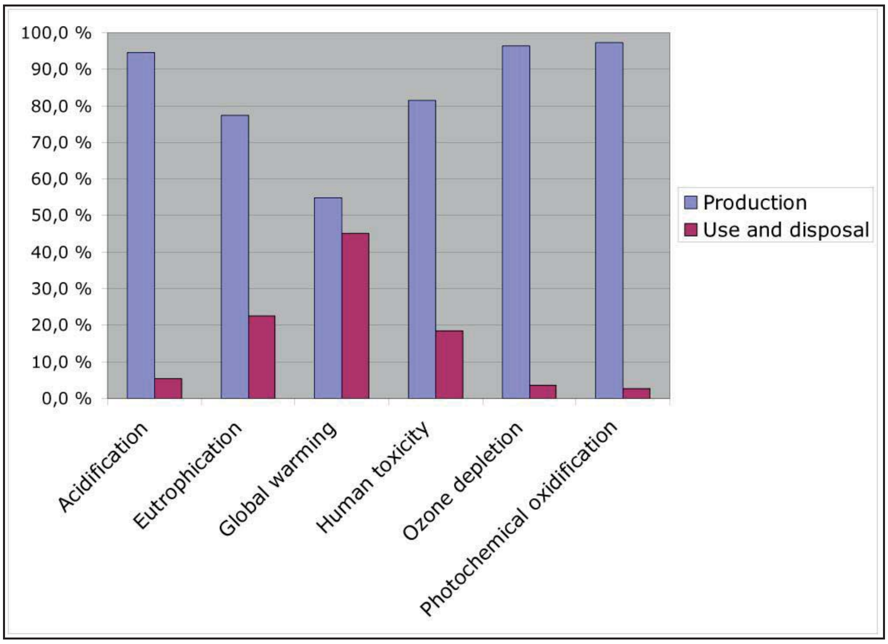


Figure 12.11. Illustration of the contribution to different impact categories in the production and use phase [Dahlsrud/Fet/Skjellum 2002, 20]

During the project period, the standardisation of environmental product information became increasingly focused, and the goal was to contribute to the standardisation by developing environmental product declarations (EPDs) according to ISO 14025 (ISO 2006).

12.4.3. The life cycle database

According to the methodology for development of EPDs as described in Chapter 4, the PCRs give the instruction to the content of the EPD. The background for the PCR-documents developed for furniture has been presented by Fet and Skaar (2006) in the article *Eco-labeling, Product Category Rules and Certification Procedures Based on ISO 14025 Requirements*. Due to the differences in the functional units for the furniture models studied in the project, three PCR-documents were made for seating, mattresses, and tables [Næringslivets Stiftelse for Miljødeklarasjoner, (NEPD) 2005abc]. One important requirement is that the information to be presented in the EPD shall be based on LCA. From the experiences in the case companies, LCA is too complex and time consuming for the SMEs to carry out. To ease the gathering of LCA-information for the companies, a specific database with LCA-information was created. One of the main challenges regarding the database was gathering and documenting a sufficient amount of site specific data. According to the requirements of the Norwegian EPD programme operator (NEPD), at least 90 % of the contribution to the total environmental impact must stem from site-specific data [NEPD, 2004]. Data for the production of resources are considered specific if they represent similar technological and geographical situations and the system boundaries are identical. The database consists of company-specific data for the assembly processes and for the majority of the sub-supplier production. The rest is based upon data from research databases, complemented with literature data for the production of a number of renewable materials not found elsewhere (e.g. textiles).

Another challenge regarding the database was its operation by the user in industry. This has been solved by using Excel as the front end for a data-assistant tool, which has the advantage of having a familiar user interface. The front end was designed so that knowledge of LCA or environmental management systems is not needed to create an EPD. The drawback of choosing this solution is that flexibility is lost compared to developing customised software and that the software is not platform independent.

As a start for the database, a few pilot models were selected. An LCA was performed for the most complex pilot for each case company [Brekke/Klæboe, 2001; Dahlsrud/Fet/Skjellum, 2002] and from the life cycle inventory (LCI), a material list for the most used materials for furniture was made. Material data and information on production processes from other pilot models were then added. This list was the specification for which data the furniture-specific LCA-database should include. To test the applicability of an industry-specific database, a life cycle inventory database was established using the LCA software GaBi [PE Europe, 2006]. The database consisted of LCI data from research databases, literature studies and data gathered from the furniture companies and their suppliers. Environmental loads were calculated using the CML2001 impact assessment method, and then entered into a Microsoft Excel spreadsheet. In an intermediate phase the data is stored in an Excel-sheet, and this is further used in a data-assisted tool for EPD-creation as illustrated in Figure 12.12. The collection of furniture-specific environmental data and the determination of the best allocation procedures were among the most time-consuming activities during the establishment of the database. Standard use and disposal scenarios for the furniture were defined and entered into the database.

Additionally, data access must be controlled so that confidential industrial information is not disclosed. This has been solved by creating individual sets of data for each participating company, in the form of a unique Excel database for each company. Although this approach keeps the data confidential, it also makes it cumbersome to upgrade database content. This could, however, be solved by creating a password protected central database, with individual access levels.

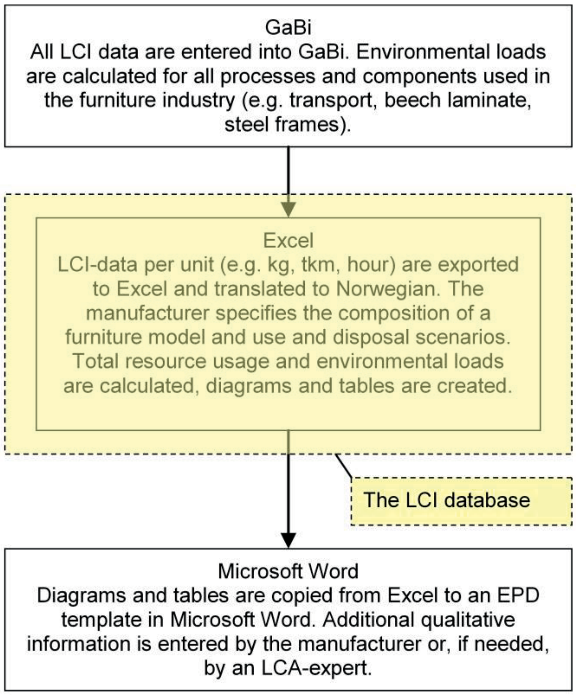


Figure 12.12. The LCI-database with information flows in/out of the database

12.4.4. Data assisted tool to help companies to create EPDs

To meet the requirements from the SMEs the tool should make it simple to model a product as a combination of specified amounts of components and processes (weight, number of pieces, hours of work, etc.). The tool should, simply put, be a "ready to use" programme for creating an EPD according to a PCR. To do this, the composition of a furniture model is specified in the Excel tool, and then the total environmental loads for the furniture are automatically calculated. This information is the basis for the EPD that is subsequently created in a Microsoft Word format. The reason for using Excel and Word was to allow the furniture companies to use programmes that they already knew how to operate.

Figure 12.13 shows how the database front-end looks for a furniture manufacturer. In the figure a piece of furniture – in this example a reclining chair – is modelled as a combination of materials and processes. The underlying LCI-data in the Excel-sheet, which are not visible to the user, are used to calculate the total environmental load. Information about the functional unit, system boundaries, and data quality requirements are stored in the Excel tool. This information is automatically added when an EPD is created. Additional information, as specified in the PCR, must be added manually by the user.

Chair I

Product category:	Seating
Seating maintained for 15 years	
Number of seats:	1
Period [year]:	15
Disposal scenario:	Scenario II
Product lifetime [year]	15

Product composition

Descrition	Material/ Process	Amount per part	Material specification	Number of parts	Waste [%]	Total
Frame						
Chair legs	Steel, type I	1.4	Steel		1.0 %	1.414 kg
Backrest	Aluminium	0.6	Aluminium		1.0 %	0..606 kg
Seat						
Upholstery	Textile, wool ▾	0.65	Textiles		8.0 %	0.702 kg
Nails		0.003	Steel	10	2.0 %	0.0306 kg
	Not included Aluminium Leather					

Figure 12.13. Creating a furniture model (example)

12.4.5. Results

Approximately 50 EPDs for Norwegian furniture have been developed as a result of the project. The format of these EPDs is based on the NIMBUS-format [Hanssen/Stranddorf/Vold/Solér/Hoffmann/Tillman, 2001]. In addition to tables and diagrams, the EPDs present the main results by a set of key performance indicators on the front page of the EPD, making it easier to compare different products against each other. This also makes it easier for non-experts to interpret the information.

As many products are part of a product family with small variations from one another, two pilot EPDs for product series have been developed [Confederation of Norwegian Business and Industry, (NHO), 2004]. Another aspect that has been examined is module declarations. To avoid the discussion around adding EPDs from cradle-to-gate and gate-to-grave up to “cradle-to-grave”-declarations, the database can be used to add the information and thus present updated EPDs accordingly. This ensures that the life cycle inventories added are consistent. As described in Chapter 4, verification of EPDs and the underlying LCA is required. Although this ensures a thorough review of both the EPD and the underlying LCA data, it may be an ineffective approach since most furniture products are made from the same materials and provided by the same sub-suppliers. This means that the same LCA data are verified repeatedly, once for each consecutive EPD. An alternative solution may be to allow for verification of the entire database. It is then sufficient to verify the procedures a company uses to create EPDs, a process that, for example, could be included in an ISO 14001 verification process.

References

Confederation of Norwegian Business and Industry (NHO) (2004a): Norske miljødeklarasjoner (EPD) – ISO/CD 14025 Environmental Declarations. <http://www.nho.no/miljo/article2680.html>, Oslo.

Dahlsrud A, Fet AM, and Skjellum M (2002): Teknisk rapport for livsløpsanalyse av stolen Bris. Working paper IØT 3/02, Department of industrial economics and technology management, Norwegian University of Science and Technology, Trondheim.

Fet AM, and Skaar C . *Eco-labeling, Product Category Rules and Certification Procedures based on ISO 14025 Requirements*. International Journal of Life Cycle Assessment, 2006:11(1), pp. 49-54, 2006.

Fet AM, Skaar C, and Riddervold, B. (2006): Miljødatabase og miljødeklarasjoner for møbler. Norwegian University of Science and Technology, Trondheim.

Hanssen OJ, Stranddorf HK, Vold M, Solér C, Hoffmann L, and Tillman A-M. *Nordic Co-ordinating System for Environmental Product Declarations* (Type III). Stiftelsen Østfoldforskning (STØ), Fredrikstad, 2001.

ISO (2006): Environmental labels and declarations — Environmental labelling Type III —Principles and procedures. EN ISO 14025:2006, Geneva.

Michelsen O, Fet AM and Dahlsrud A. *Eco-efficiency in extended supply chains: a case study of furniture production*. Journal of Environmental Management 79: 290-297, 2006.

Næringslivets Stiftelse for Miljødeklarasjoner (NEPD) (2004): Retningslinjer for Næringslivets Stiftelse for Miljødeklarasjoner. Norsk tilpasning av ISO/CD 14025. Oslo.

Næringslivets Stiftelse for Miljødeklarasjoner (NEPD) (2005a): PCR for Seating. <http://www.nho.no/files/NPCR03SeatingEN_1.pdf>, Oslo.

Næringslivets Stiftelse for Miljødeklarasjoner (NEPD) (2005b): PCR for Beds and Mattresses. <http://www.nho.no/files/NPCR04BedsEN.pdf>, Oslo.

Næringslivets Stiftelse for Miljødeklarasjoner (NEPD) (2005c): PCR for Tables. <http://www.nho.no/files/NPCR05TableEN.pdf>, Oslo.

PE Europe GmbH (2006): GaBi 4 Software. <http://www.gabi-software.com>, Stuttgart.

Appendix 3

Product category rules and environmental product declarations as tools to promote sustainable products: experiences from a case study of furniture production.

DOI: 10.1007/s10098-008-0163-6

Is not included due to copyright

Appendix 4

Accountability in the Value Chain: From Environmental Product Declaration (EPD) to CSR Product Declaration.

DOI: 10.1002/csr.275

Corporate Social Responsibility and Environmental Management
Corp. Soc. Responsib. Environ. Mgmt. (2011)
Published online in Wiley Online Library
(wileyonlinelibrary.com) **DOI:** 10.1002/csr.275

Accountability in the Value Chain: From Environmental Product Declaration (EPD) to CSR Product Declaration

Christofer Skaar* and Annik Magerholm Fet
Norwegian University of Science and Technology, Trondheim, Norway

ABSTRACT
Reporting on corporate social responsibility (CSR) performance to external stakeholders is a key element of corporate and value chain accountability. This paper identifies gaps in existing value chain reporting practices and examines options for how a CSR product declaration can be developed to address these gaps. The characteristics of six state-of-the-art accountability management, reporting, and certification approaches are identified and the pairwise correlations are assessed statistically. Findings show that the overall correlation is low; there is no low-hanging fruit for combining existing elements. Missing allocation and aggregation methods are a particular challenge, especially concerning social aspects in the value chain. Three options for a CSR product declaration based on the Environmental Product Declaration (EPD) are presented. Building on the strength of the EPD (transparency, quantification, and verification), a scientific consensus building approach is recommended. Indicator development becomes a balancing act between satisfying internal management requirements and keeping connected with the scientific development. Copyright © 2011 John Wiley & Sons, Ltd and ERP Environment.

Received 4 February 2011; revised 27 April 2011; accepted 29 April 2011
Keywords: corporate social responsibility; product declarations; accountability; reporting; value chains

Introduction

Business is facing ever increasing demands to act responsible, as reflected in the rise of interest in corporate social responsibility (CSR) over six decades (Carroll, 1999). These demands are not limited to single companies or single issues. The focus is now on the whole value chain from cradle to grave, covering economic, social, and environmental issues (Porter and Kramer, 2007). Accountability to external stakeholders is a key element of being responsible (Zadek, 2007), which has implications for value chain reporting practices. This paper identifies gaps in existing reporting practices and examines to what extent Environmental Product Declarations (EPDs) (ISO, 2006) can be developed into CSR product declarations that can fill these gaps and thereby provide quantified information to stakeholders. This is done by first evaluating existing

*Correspondence to: Christofer Skaar, Department of Industrial Economics and Technology Management, Norwegian University of Science and Technology, 7491 Trondheim, Norway. E-mail: skaar@iot.ntnu.no
The PhD position of Christofer Skaar is part of a research programme sponsored by the Norwegian Research Council. Project name: C(S)R in global value chains, a conceptual and operational approach. Project number: 171658.

accountability approaches and their key characteristics, and subsequently analysing the correlation between the different approaches statistically. The results provide the basis for a discussion of options for developing a CSR product declaration based on the EPD approach. CSR is here defined as the voluntary integration of economic (anti-corruption, investment policies, etc.), social (labour standards, human rights, societal impact, etc.) and environmental (resource extraction, emissions, wastes, etc.) aspects into business activities (Dahlsrud, 2006).

The Corporation, the Extended Supply Chain and the Product Life Cycle

There are three different systems of interest that a CSR product declaration should take into consideration. The first system is the *corporation*, covering the activities of a single entity. This can be a corporation, a production site, or a business unit within a corporation. The second system is the *extended supply chain*. This is the traditional supply chain, defined as a 'network of connected and interdependent organisations mutually and co-operatively working together to control, manage and improve the flow of materials and information from suppliers to end users' (Christopher, 2005), extended to include the use and end of life stages. The third system is the *product life cycle*. Here the system consists of the individual processes in the value chain, and does not include the corporations.

The term 'value chain' here refers collectively to the two last systems: the extended supply chain and the product life cycle. To what degree sub-systems (*corporations* for the extended supply chain and *processes* for the product life cycle) are included can vary from case to case, depending on which aspects we are investigating and how cut off criteria are defined (i.e. what is excluded from the system in order to reduce complexity).

The scope of this study is limited to quantified CSR information relating to the three defined systems of interest, with a particular focus on how to communicate quantified CSR information through product declarations.

Accountability

Before analysing how a product declaration providing CSR information can be developed, the terms 'accountability' and 'reporting' will be introduced. This is followed by an overview of the most significant accountability approaches, providing an overview of the state of the art of what is currently in use. The applicability of the approaches in relation to the three systems of interest will furthermore be analysed.

Accountability implies that the corporation is accountable to someone, for example, to external stakeholders. Being accountable means that the information you provide is verified and that the results are made public (Sethi and Emelianova, 2006). There is a plethora of frameworks, guidelines, standards, certifications, labels, and declarations available to corporations to facilitate managing, accounting, and reporting CSR performance. As responsibility is no longer limited to activities within a single corporation, impacts caused by suppliers and sub-suppliers should therefore be taken into consideration (European Commission, 2004). This includes the use and disposal stages of products and services (Lenzen *et al.*, 2004).

Reporting is based on the assumption that you can't manage what you're not measuring (Foran *et al.*, 2005). Performance indicators reported for different systems and at different levels 'must be compatible with other performance indicators to prevent the decision-makers from receiving contradictory control signals' (Kjellén, 2000).

CSR reporting for the corporate system has emerged from traditional financial accounting. The practice of including social and environmental aspects in corporate financial reports is often referred to as triple bottom line (TBL) reporting, where the Global Reporting Initiative (GRI) is a prominent example (Lamberton, 2005).

Value-chain reporting is commonly in the form of labels or declarations. A label is a report that confirms specific requirements have been met, where requirements can be on a single aspect (e.g. dolphin-safe tuna) or on multiple economic, social, and environmental aspects. A label provides a confirmation that all the label requirements have been met, but does not give a quantified report of the performance. A declaration, on the other hand, provides a quantified account for specific aspects related to the product but does not set specific performance requirements. Instead it is the quality of the report that is in focus, with the intention of providing objective information (ISO, 2006).

DOI: 10.1002/csr

Six Degrees of Accountability

Accountability approach is here used as a collective term to describe any systematic or standardised approach intended to be used by a corporation to provide information to internal and external stakeholders about environmental or social aspects. Six such approaches are analysed. The six are the GRI (GRI, 2010a), AccountAbility 1000 (AA1000) (AccountAbility, 2010), ISO 14001(ISO, 2004), Social Accountability 8000 (SA8000) (SAI, 2010c), Environmental Product Declarations Type III (EPD) (ISO, 2006) and product labelling schemes (ISO, 2000). The selection criteria were that they must deal with social or environmental aspects, be globally applicable, acknowledge external stakeholders, and be internationally recognised.

Table 1 gives an overview of the six selected approaches. The left column shows how they can be classified according to type: two are management standards (AA1000 and ISO 14001), two are certification schemes (SA8000 and product labelling), and two are reporting schemes (GRI and EPD). This classification is based on the main features and is not mutually exclusive; there is, for example, a requirement in SA8000 that a management system is in place but it is nevertheless classified as a certification approach in Table 1. The middle column provides a brief description of each approach. In the far right column, the scope of each approach is presented in relation to the three defined systems of interest in value chain gaps, again based on the main features of the approaches. The table shows that the EPDs and labelling schemes are the only ones focusing on the entire value chain, whilst the other four deal with corporations.

The Value Chain Gaps

From Table 1, two gaps can be identified that relate to CSR reporting in the value chain. The first gap is that no approach was found dealing with both the extended supply chain and the product life cycle that matched the selection criteria (e.g. standardised, internationally recognised, and globally applicable). This supports previous studies calling for a combined approach (Hutchins and Sutherland, 2008; Erlandsson and Tillman, 2009; Kaenzig *et al.*, 2011). The second gap is that no value chain reporting approach was found dealing with both social and environmental aspects, confirming that the findings of Ness *et al.* (2007) in this regard still hold true for product reporting. It should also be noted that no standardised management approach for the value chain (neither extended supply chain nor product life cycle) could be found that met the criteria, but this is beyond the scope of this study to address.

Without combining the extended supply chain and the product life cycle it will be possible to legitimise corporations that are engaging in unsustainable business practices (Flydal, 2006). According to Jørgensen *et al.* (2009), such a combined approach is also in line with how a number of major Danish companies perceive their responsibilities in the supply chain.

Analytical Framework

Having identified two gaps related to CSR reporting in the value, the next step is to analyse the possibility for addressing these gaps. The initial assumption is that it is possible to combine elements from the state of the art of accountability and develop the EPD into a CSR product declaration. In order to test this assumption, the characteristics of the accountability approaches will be identified and subsequently compared. The analytical framework used for this purpose is based on Lamberton's sustainability accounting framework (2005), enriched and validated through a literature review of accountability analyses as described below. Lamberton's framework was chosen because it was the most comprehensive model found in the literature review, linking sustainability, accounting and reporting.

The findings of the literature review were used to enrich and validate the criteria and sub-criteria in the analytical framework (criteria in column 2 and sub-criteria in column 3 in Table 2). Sixteen analyses of accountability approaches were reviewed (Line *et al.*, 2002; Hammond and Miles, 2004; Lenzen *et al.*, 2004; Finnveden and Moberg, 2005; Foran *et al.*, 2005; Krajnc and Glavic, 2005a, 2005b; Waage *et al.*, 2005; Lamberton, 2005; Pintér *et al.*, 2005; Szekely and Knirsch, 2005; Vanclay, 2006; Ness *et al.*, 2007; Hutchins and Sutherland, 2008;

DOI: 10.1002/csr

		Description	System
Management	**AccountAbility 1000 (AA1000)**	AA1000 was launched in 1999 by AccountAbility, and is both a management standard (learning from and building on from for example ISO9001 and ISO14001) and a disclosure standard. The AA1000 is designed to complement other company disclosure approaches, such as the GRI Reporting Guidelines. (McIntosh, 2003)	**Corporation** The system is dependent on the outcome of stakeholder dialogue and company resources. It may extend beyond the reporting organisation to include suppliers and customers.
	ISO14001	ISO14001 was developed by the International Organization for Standardization (ISO) with intent to "provide organizations with the elements of an effective environmental management system" (ISO, 2004). The standard is compatible with the ISO9001 standard for quality management.	**Corporation** "[E]nvironmental aspects that the organization identifies as those which it can control and those it can influence" (ISO, 2004). This includes processes, products and services, but does not demand a value chain approach. (ISO, 2004)
Reporting	**Global Reporting Initiative (GRI)**	The Global Reporting Initiative was established in 1997 by CERES and UNEP, to develop global guidelines on economic, social and environmental performance reporting. GRI is an independent, multi-stakeholder international body which maintains, disseminates and develops the GRI guidelines. The GRI is funded by several corporations and nations. (CERES, 2011)	**Corporation** "The Sustainability Report Boundary should include the entities over which the reporting organization exercises control or significant influence both in and through its relationships with various entities upstream (e.g., supply chain) and downstream (e.g., distribution and customers)." (GRI, 2011)
	Type III Environmental Product Declarations (EPD)	ISO14025 concern type III environmental declarations, which are commonly referred to as Environmental Product Declaration (EPD). The purpose of an EPD is to enable comparisons between products or services fulfilling identical functions. The comparisons are based on life cycle assessments (LCA) performed of the products and services according to a set of Product Category Rules (PCR) and the ISO14040-series.	**Value chain: product life cycle** Product or service life cycle, specified in detail in a set of Product Category Rules (PCR). PCR documents are intended to be internationally valid, so that there for each product group should only be one PCR document.
Certification	**Social Accountability 8000 (SA8000)**	SA8000 was developed by the Social Accountability International (SAI), aninternational, multi-stakeholder advisory board with representatives from NGOs, business, trade unions and governments. (SAI, 2010b) The main focus of the SA8000 standard is improving working conditions and securing workers rights. (SAI, 2010a)	**Corporation** The reporting organisation is responsible for selecting supplier based on their ability to meet the requirements in the standard. This responsibility can also be extended to sub-suppliers.
	Product labelling schemes	There is a multitude of product/service labelling schemes in use today. In this assessment the Nordic Swan, the EU Flower and Fairtrade have been examined. The results are general, based primarily on these labels in addition to a number of specific-issue labels (Dolphin Safe).	**Value chain** Several overlapping systems can be found, with elements of: • Product or service life cycle • Supply chain • Organisation • Use phase (e.g. allergy tested) • End of life (e.g. biodegradable)

Table 1. Description of and system of interest for six accountability approaches

DOI: 10.1002/csr

Erlandsson and Tillman, 2009; Rasche, 2009). Criteria from these were included if they did not overlap other criteria (redundancy) and if they were found in two instances or more (relevance).The result was that 11 criteria were included in the analytical framework, consisting of a total number of 30 sub-criteria.

The analysis concerns the key characteristics of the six accountability approaches. The purpose is to (1) identify general characteristics of accountability approaches, (2) analyse the level of correlation between them, and (3) compare the EPD with management, reporting, and certification approaches. The analytical framework used to characterise the approaches is based on three groups of characteristics: objectives, principles, and techniques. The three groups consisted in total of 11 criteria and 30 sub-criteria. Each group in the analytical framework is described below, and the framework is shown in Table 2. The results of this analysis provide the basis of the discussion in the next section of options for how an EPD can be developed to a CSR product declaration.

Characterising Accountability: Objectives, Principles, and Techniques

The criteria and sub-criteria for the three groups of characteristics are described below. The number in parenthesis behind each criterion refers to its location in Table 2, third column.

The criteria for *objectives* of an accountability approach are purpose (1), object (2) and system (3). Purpose distinguishes between descriptive versus prescriptive approaches (Ness *et al.*, 2007), also termed as attributional versus consequential approaches (Ekvall and Weidema, 2004). Object refers to which system is targeted, ranging from policies and regions to organisations, products, and substances (Lenzen *et al.*, 2004; Finnveden and Moberg, 2005; Foran *et al.*, 2005; Rasche, 2009). System is used to define the system of interest and to describe what is included and what is excluded (Foran *et al.*, 2005; Waage *et al.*, 2005).

The criteria for *principles* are scope (4), time period considered (5) and update frequency (6). Scope concerns to which extent the integration of nature-society systems (economic, social, environmental) are covered (Ness *et al.*, 2007; Rasche, 2009). Time period considered and update frequency deal with the temporal aspects that are suggested or required. The former is the time period considered in a typical report (e.g. financial year or product life span) and the latter is how often a report is updated or renewed (Lamberton, 2005).

The criteria for *techniques* are method (7), indicators used/suggested (8), aggregation methods for performance indicators (9), impact assessment (10) and verification (11). The method criterion is used to evaluate which type of accounting method is used (Lamberton, 2005). The criteria indicators describe whether or not mandatory or voluntary performance indicators are specified. If an accountability approach suggests performance indicators, aggregation methods for the performance indicators are examined and used to evaluate if and how quantified indicators are aggregated (e.g. weighting, characterisation, and index construction) (Foran *et al.*, 2005; Krajnc and Glavic, 2005a, 2005b; Pintér *et al.*, 2005; Szekely and Knirsch, 2005; Hutchins and Sutherland, 2008). Environmental impact assessment describes which, if any, impact assessment methodologies are suggested or required (Finnveden and Moberg, 2005; Erlandsson and Tillman, 2009). Social impact assessment (SIA) is primarily performed in a regulatory context. It is therefore not included in this analysis, although corporations have been recommended to include SIA as part of their CSR strategy processes (Vanclay, 2006). Verification concerns the verification requirements; mandatory or voluntary, independent or internal (Line *et al.*, 2002; Hammond and Miles, 2004; Szekely and Knirsch, 2005). Verification can increase the credibility of the reported information (Azzone *et al.*, 1997).

Characteristics of Accountability Approaches

Three criteria are common for all frameworks, as shown in Table 2; they all focused on verification (11ab) and on stakeholder involvement (4e). Three criteria were common for all but one approach (1a, 6ab). An attributional perspective (1a) could be used in all approaches, but the management approaches had a stronger focus on consequential approaches (1b). For update frequency both criteria (6ab) were applicable to five frameworks each. This illustrates the flexibility of the approaches, it is often left to the user to adopt and adapt. It should also be mentioned that none of the criteria are mutually exclusive by default.

DOI: 10.1002/csr

	Criteria	Sub-criteria	#	AA1000	ISO14001	GRI	EPD	SA8000	Prod. label
Objectives	**Purpose**	*Attributional (descriptive)*	1a	x	(x)	x	x[a]	x	x
		Consequential (prescriptive)	1b	x	x		x		
	Object	*Policies, plans, programmes and projects*	2a						
		Regions or nations	2b			(x)			
		Organisations, companies	2c	x	x	x		x	
		Products and services	2d		(x)	(x)	x	(x)[b]	x
		Substances	2e						
	System	*Corporate*	3a	x	x	x		x	
		Value chain	3b				x		x
Principles	**Scope**	*Economic*	4a			x			x
		Environmental	4b		x	x	x		x
		Social	4c	x		x		x	x
		Business ethics	4d	x				x	x
		Stakeholder	4e	x	x	x	x	x	x
	Time period considered	*One year or less*	5a	x	x	x	(x)[c]	x	x
		More than one year	5b	x[d]	x[d]		x	x	x[e]
	Update frequency	*At least annual*	6a	x	x	x[f]		x[g]	(x)
		Less than annually	6b	x[h]	x[i]		x[j]		x[k]
Techniques	**Method**	*Sustainable cost*	7a						
		Natural capital inventory accounting	7b						
		Input-output analysis	7c				x		x
		Full-cost accounting	7d						
		Triple bottom line	7e			x			
		Other approaches	7f	x	x[l]			x	x
	Indicators	*Mandatory*	8a		[m]	x[n]	x	[m]	[o]
		Voluntary	8b	x[p]		x[q]	(x)[r]		
	Aggregation methods for performance indicators (not including additive aggregation)		9			x[s]	[t]		[u]
	Environmental impact assessment		10	n/a		[v]	x	n/a	
	Verification	*Mandatory*	11a				x[w]	x[x]	(x)[y]
		Voluntary	11b	x[#]	x[+]	x[*]			

Table 2. Common characteristics of accountability approaches, by objectives, principles and techniques

[a] Depending on the way the underlying LCA is performed, the EPD can be either attributional or consequential.
[b] Indirectly, focusing on suppliers' and sub-suppliers' products.
[c] For products with very short lifetime.
[d] Can vary between different aspects.
[e] Depending on product type and aspects in focus.
[f] Recommended.
[g] Continuous documentation required.
[h] Regular is advised, but not necessarily as frequent as annually.
[i] Depending on the circumstances of the organisation.
[j] Usually two to five years.
[k] Renewal of label usually required after a specified time.
[l] Any which the organisation sees fit to suit their environmental management system.
[m] Indicators are mandatory, but they are not specified.
[n] Core indicator set.
[o] The label is the indicator, awarded on performance.
[p] Indicators are developed by the reporting organisation in dialogue with its stakeholders.

DOI: 10.1002/csr

[q]Additional indicator set.
[r]supplemental environmental information, the allowed type is usually specified in PCR.
[s]Composite indicators, not aggregated.
[t]Characterisation (i.e. aggregation based on potency instead of physical weight of resources/emissions).
[u]No aggregation, but often a set of threshold levels.
[v]No, only emissions in weight.
[w]Independent verification is required, but programme operator can decide if this means internal or third party. Verification type must be stated on the front page of the EPD.
[x]Mandatory certification. Audits can be triggered by anyone providing evidence of non-compliance.
[y]Third party independent verification is common.
[#]The AA1000 framework includes an assurance standard that can be used for third party independent assurance.
[+]Third-party certification common.
*Voluntary, but *external assurance* (an assessment of the report by an objective group of outsiders) is recommended.

Five criteria were not applicable to any of the analysed frameworks. Three of these were concerned with accounting method, showing that the approaches of sustainable cost (7a), natural capital inventory (7b) and full-cost accounting (7d) were not used in any of the frameworks. Furthermore, none of the frameworks are primarily intended to be used on regions, nations, policies, plans or programmes (2a) or substances (2e). The remaining 17 criteria were applicable to one to four frameworks (3, 4, 3, and 6 criteria respectively). Diversity rather than commonality appears to be the rule.

All the accountability approaches analysed here are concerned with verification, but in three of six of the frameworks, this step is voluntary. This is a considerable weakness when it comes to reporting to external stakeholders. Third party assurance is often recommended, but only required by SA8000 and product labels (e.g. Nordic Swan and EU Ecolabel). This flexibility can help to develop an organisation's reporting routines, but does not necessarily increase the organisation's credibility (Park and Brorson, 2005).

Correlation between Approaches

Correlations between the accountability approaches were assessed using the Jaccard index (SPSS, 2010), a statistical comparison calculating the pairwise correlation for all the sub-criteria with equal weight to each sub-criterion. Joint absences are excluded. If all sub-criteria match, we have perfect correlation and a score of 1; if none of the sub-criteria match we get a score of 0. The Jaccard index was chosen because it allows for a comparison based on what the accountability approach is, not on what it isn't. Table 2 was translated into a binary matrix with 1 indicating a presence and 0 indicating an absence for each sub-criterion for each accountability approach. Only values of 'x' in the table are counted as presence. Values of '(x)', 'n/a' and blank cells are counted as absences. The matrix was used to calculate the Jaccard index of pairwise comparisons, as shown in Table 3.

Table 3 shows that the highest correlation is between AA1000/SA8000 ($J = 0.71$) and AA1000/ISO 14001 ($J = 0.67$). The lowest correlation is between SA8000/EPD ($J = 0.32$) and GRI/AA1000 ($J = 0.4$). Summing the results for all pairwise comparisons for each accountability approach to see overall correlation reveals that ISO14001 and product labels have the highest sums ($J_{tot} = 2.85$ and $J_{tot} = 2.80$) and GRI and EPD have the lowest sums ($J_{tot} = 2.22$ and $J_{tot} = 2.24$). The largest difference in correlation is for SA8000 correlated with AA1000 and EPD ($J_{SA8000/AA1000} = 0.71$ and $J_{SA8000/EPD} = 0.32$, $J_{diff} = 0.40$). The lowest difference found is for GRI, with correlations between 0.4 and 0.5 giving a difference of 0.1 or below. The complete results are given in Table 3 below.

There is a higher correlation between management approaches or approaches with elements of management (AA1000, ISO14001 and SA8000) than others, but the results do not reveal any grouping related to system (corporate, value chain). Reporting approaches (GRI and EPD) score lower on overall correlation, including intercorrelation ($J_{GRI/EPD} = 0.45$). The EPD system has 7 criteria in common with GRI; purpose, object products, mandatory and voluntary indicators, environmental scope, stakeholder focus and time period. 8 criteria are in the EPD system but not in the GRI and vice versa. More generally the results reveal the diversity of the approaches, the highest correlation found was only 0.69.

DOI: 10.1002/csr

Product Declarations: Characteristics and Correlation

Table 2 shows that two criteria were unique to the EPD system; aggregation method (9) and environmental impact assessment (10). Although there is a general scientific consensus on how to perform quantified environmental impact assessment and aggregation for a number of impact categories, this does not translate into specification in the analysed accountability approaches. This could be related to a perception of uncertainty; there is for example still methodological development in this area (Goedkoop *et al.*, 2009). It should be mentioned that no similar level of scientific consensus exists for quantified social impacts (Benoît *et al.*, 2010).

Two criteria were common for the EPD approach and one other approach, product labelling. The first was the value chain criteria (3b) (obviously, as only two value chain approaches were found) and the second was the use of input-output methodology (7c) (e.g. LCA) which can be required in product labels that have a life cycle approach. The results are not usually communicated publically, except for CO_2 labelling (Vanclay *et al.*, 2010). In most instances the label only certifies that a defined threshold has not been crossed.

The EPD approach has 6 criteria in common with the management approaches; purpose (1ab), stakeholder scope (4e), time period (5ab) and update frequency (6b). For certification approaches there are 6 criteria in common with the EPD; attributional purpose (1a), object (2d, product), stakeholder scope, time period (both criteria) and verification. Where purpose and stakeholder scope is similar, this indicates that there is a potential for aligning these approaches.

The results in Table 3 show that the EPD approach has the lowest correlation with the other approaches. An optimistic interpretation is that this indicates a potential for developing the EPD by drawing on the other approaches, but the lack of correlation can also be interpreted as an indicator of inherent compatibility challenges.

Discussion

The results from the correlation analysis in Table 3 show that the correlation between the EPD and the five other accountability approaches is low. The results indicate that there is no other accountability approach that can readily be combined with the EPD to address the identified gaps; there is no low-hanging fruit waiting to be picked.

The Need to go Beyond the EPD

The EPD is flexible to a certain degree when it comes to including additional information; which types of additional information can or should be included is specified for each product group. Currently two types of corporate

		Management		Reporting		Certification	
		AA1000	ISO14001	GRI	EPD	SA8000	Prod.label
Management	**AA1000**	-	0,69	0,43	0,36	0,69	0,48
	ISO14001	0,69	-	0,45	0,45	0,63	0,50
Reporting	**GRI**	0,43	0,45	-	0,39	0,45	0,43
	EPD	0,36	0,45	0,39	-	0,32	0,57
Certification	**SA8000**	0,69	0,63	0,45	0,32	-	0,58
	ProdLabel	0,48	0,50	0,43	0,57	0,58	-
Sum		**2,64**	**2,71**	**2,15**	**2,09**	**2,66**	**2,56**
Max difference		0,32	0,24	0,06	0,25	0,37	0,14

Table 3. Pairwise comparison, Jaccard index

DOI: 10.1002/csr

information can be required to be included in an EPD according to the ISO 14025, if deemed relevant for a product category by the programme operator. The first is if the corporation has a certified environmental management system and the second is if there are other environmental activities in the organisation such as recycling programmes (ISO, 2006). A third variant is a specific section in the EPD where the corporation can include additional information, with restrictions on content (e.g. biodiversity impacts, management systems and activities, geographical aspects, hazard and risk, and absence or presence of materials (ISO, 2006)).

The EPD flexibilities described above can however not address the gaps identified earlier, primarily because the EPD by definition is limited to environmental aspects. Developing a CSR product declaration requires going beyond the current EPD. A CSR product declaration that addresses all three systems of interest is needed. This is necessary to avoid problem shifting between the systems (Korhonen, 2003) and problem shifting between economic, social, and environmental aspects.

A proposed solution is to draw on other accountability approaches, based on the initial assumption that there are elements that can be combined to create a CSR product declaration. Two proposed options are in line with the definition of a product declaration as dealing with quantified accountability. Both options depart from the scope of the current EPD, as they require going beyond environmental aspects. The first option is to draw on the GRI, the only other accountability approach analysed here that has a defined indicator set. The second option is to use the accountability approaches as a reference when identifying CSR aspects for the product life cycle and for the extended supply chain, and subsequently developing indicators for these. A third option is to deviate from the quantitative nature of the EPD and explore the use of qualitative indicators. The three options are discussed in more detail below. The three options are not mutually exclusive. If possible, all indicator development should be linked to existing management systems within the reporting organisation (Searcy *et al.*, 2008).

Building on GRI Indicators

The first option is to draw on the GRI indicator framework (GRI, 2010b) which is a structured and widely used approach for sustainability and CSR reporting for corporations (Krajnc and Glavic, 2005b; Szekely and Knirsch, 2005). The GRI indicator framework organizes the performance indicators in a hierarchy based on the triple bottom line. There are 6 categories spanning 34 aspects, with a total of 79 performance indicators specified (54 core and 25 additional) (GRI, 2010b).

The GRI indicators have been developed for corporate reporting and were not designed to address social or environmental aspects in the value chain. Of the 30 environmental indicators, only 16 can be related to processes based on physical properties such as mass or energy (GRI, 2010b). The rest are related to the organisation itself (e.g. strategies, initiatives, overall expenditures). In order for these indicators to make sense in a product declaration, they must be related in a meaningful manner to the value chain through allocation, aggregation or a combination. This allows for answering questions such as 'what percentage of my supply chain has attribute X?' (Andrews *et al.*, 2009). Where several different indicators all contribute to a specific impact category, methods for developing characterisation factors that relate the relative contribution of each indicator are needed. Indicators can either be consistent with the recommended scientific approach that is used in the EPD (ISO, 2006), or they can go beyond this and rely on value judgements instead of observed scientific mechanisms.

Validating CSR indicators

The second option is to draw on one or more of the accountability approaches when developing new indicators for a CSR product declaration. This has two potential advantages. The first is a validation of social and environmental aspects that are selected as they have already undergone a stakeholder evaluation process. The second advantage is that contradictory indicators for corporations and value chains are not created. The disadvantage is that in most of the accountability approaches it is left to the individual corporation to decide on which indicators to use, which means that conflicting indicators may be developed by different corporations. Furthermore, this option may lead to less coordination of indicators and increased diversity (a scenario termed by Pintér *et al.* (2005) as 'indicator zoo'), and it does not resolve the need for allocation, aggregation and characterisation methods.

DOI: 10.1002/csr

Developing a Qualitative CSR Product Declaration

The third option is to depart from the quantitative nature of the EPD. The advantage of this option is that it makes it possible to cover a broader range of social aspects that there currently are no agreed upon quantitative indicators for. The disadvantage is that the goal of objectiveness of the CSR declaration will be compromised, potentially leading to reduced transparency, credibility, and comparability. This approach is therefore only recommended if the declaration is intended as a part of a long-term stakeholder dialogue or internal value chain development, and not as a tool for accountability or product comparison. This third option erodes the EPD's strength of going towards scientific consensus, as there are no agreed upon, consensus-based approaches for dealing with qualitative CSR issues in the value chain.

Obstacles and Opportunities

The analysis has identified gaps that should be addressed in order to report on CSR in the value chain. However, in order to address these gaps there are a number of issues to be resolved and limitations to be aware of. The first is the linkage to top-down reporting frameworks at national, regional, and global level. Without such linkage it will not be possible to evaluate if and to what degree a product is contributing to overall sustainability. The second is that an attributional approach to reporting will not be able to take into account rebound effects and non-linear behaviour (Finnveden *et al.*, 2009). The third is the gathering of specific data, which is important for both environmental (Mutel and Hellweg, 2009) and social aspects (Dreyer *et al.*, 2010). This is especially important when it comes to social aspects, as these are not in any way reflected in the product itself. In contrast, many environmental aspects will often be directly identifiable in the product (e.g. material choices, content of hazardous substances). A fourth issue is the system boundaries. It is necessary to make clear what is beyond the scope of the product declaration, as not to give the impression that the declaration covers all CSR aspects.

Businesses that include social and environmental issues in their value chain considerations often do so in part because of external pressure (Kolk, 2008 l; Gold *et al.*, 2009). A response to pressure from external stakeholders is to be transparent and accountable, for example through product reporting. Producing such reports can be a time- and resource-consuming process, but can at the same time be a supporting factor for sustainable supply chain management practices (Seuring and Muller, 2008).

Drawing on the GRI approach to develop indicators for a CSR product declaration takes advantage of the stakeholder dialogue processes that have developed these indicators, but will in general not ease data gathering especially when considering small and medium-sized enterprises (SMEs). The total number of enterprises in the EU 27 is approximately 20 million, where only 40 000 are not SMEs. Of these, fewer than 700 are reporting in compliance with GRI (Schmiemann, 2008). It is furthermore important that the data collection is uniform and globally applicable, to avoid accelerating 'into data gridlock and management apathy where the complexity of the reform agenda overwhelms the reformers and their institutions' (Foran *et al.*, 2005).

Conclusions and Further Research

This study has shown that there are gaps in current reporting practices. Integrated reporting on economic, social, and environmental aspects exists only for one of the three systems of interest: the corporation. Hence there is a need to integrate economic, social, and environmental aspects in value chain reporting, and value chain reporting should include both the extended supply chain and the product life cycle.

Analysing the characteristics of six different accountability approaches has shown the diversity when it comes to dealing with accountability. The correlation between the six is low ($J < 0.7$). The extended supply chain is not addressed in any of the six, and furthermore only the EPD deals with quantified reporting for the product life cycle. Based on this, the EPD appears as the most promising candidate for further development into a CSR product declaration, even though it has the lowest overall correlation of the six.

Building on the EPD as a basis for a CSR product declaration has several advantages, transparency and quantification being two. The initial assumption was that it is possible to develop a CSR product declaration by

DOI: 10.1002/csr

combining elements from existing accountability approaches. This study shows that work remains before this can be realised, especially as allocation, aggregation and characterisation methods are missing for social aspects and for the extended supply chain. Following the principles of the EPD and LCA in general, a scientific consensus building approach is recommended.

A CSR product declaration can help to avoid problem shifting from one system to another and from one aspect to another. Selecting indicators is, however, a balancing act, where the needs of both internal (e.g. integration with existing management systems) and external stakeholders (e.g. transparency, comparability) must be considered, and this will be a matter for further research.

References

AccountAbility. 2010. The AA1000 Standards. http://www.accountability.org/standards/index.html [8 December 2010].

Andrews E, Lesage P, Benoît C, Parent J, Norris G, Revéret J-P. 2009. Life cycle attribute assessment - case study of Quebec greenhouse tomatoes. *Journal of Industrial Ecology* **13**(4): 565–578.

Azzone G, Brophy M, Noci G, Welford R, Young W. 1997. A stakeholders' view of environmental reporting. *Long Range Planning* **30**(5): 699–709.

Benoît C, Norris G, Valdivia S, Ciroth A, Moberg A, Bos U, Prakash S, Ugaya C, Beck T. 2010. The guidelines for social life cycle assessment of products: just in time! *International Journal of Life Cycle Assessment* **15**(2): 156–163.

Carroll AB. 1999. Corporate social responsibility: Evolution of a definitional construct. *Business Society* **38**(3): 268–295.

CERES. 2011. Global Reporting Initiative (GRI). http://www.ceres.org/Page.aspx?pid=435 [4 February 2011].

Christopher M. 2005. *Logistics and Supply Chain Management: Creating Value-Adding Networks*, 3rd ed. Prentice Hall/Financial Times: London.

Dahlsrud A. 2006. How corporate social responsibility is defined: an analysis of 37 definitions. *Corporate Social Responsibility and Environmental Management* **15**(1): 1–13.

Dreyer L, Hauschild M, Schierbeck J. 2010. Characterisation of social impacts in LCA. Part 2: Implementation in six company case studies. *International Journal of Life Cycle Assessment* **15**(4): 385–402.

Ekvall T, Weidema BP. 2004. System boundaries and input data in consequential life cycle inventory analysis. *International Journal of Life Cycle Assessment* **9**(3): 161–171.

Erlandsson J, Tillman A-M. 2009. Analysing influencing factors of corporate environmental information collection, management and communication. *Journal of Cleaner Production* **17**(9): 800–810.

European Commission. 2004. European Multistakeholder Forum on Corporate Social Responsibility - Final Results & Recommendations. European Commission: Brussels.

Finnveden G, Hauschild MZ, Ekvall T, Guinee J, Heijungs R, Hellweg S, Koehler A, Pennington D, Suh S. 2009. Recent developments in life cycle assessment. *Journal of Environmental Management* **91**(1): 1–21.

Finnveden G, Moberg A. 2005. Environmental systems analysis tools - an overview. *Journal of Cleaner Production* **13**(12): 1165–1173.

Flydal EF. 2006. WWF hjelper piratfiskerne. Dagbladet: Oslo.

Foran B, Lenzen M, Dey C, Bilek M. 2005. Integrating sustainable chain management with triple bottom line accounting. *Ecological Economics* **52**(2): 143–157.

Goedkoop M, Heijungs R, Huijbregts MAJ, Schryver AD, Struijs J, Zelm RV. 2009. ReCiPe 2008. A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. Dutch Ministry of Housing, Spatial Planning and Environment: The Hague.

Gold S, Seuring S, Beske P. 2009. Sustainable supply chain management and inter-organizational resources: a literature review. *Corporate Social Responsibility and Environmental Management* **17**(4): 230–245.

GRI. 2010a. Global Reporting Initiative. http://www.globalreporting.org [20 January 2010].

GRI. 2010b. Performance Indicators. http://www.globalreporting.org/ReportingFramework/G3Online/PerformanceIndicators/ [6 December 2010].

GRI. 2011. General Reporting Notes. http://www.globalreporting.org/ReportingFramework/G3Guidelines/AboutG3GeneralReportingNotes.htm [4 February 2011].

Hammond K, Miles S. 2004. Assessing quality assessment of corporate social reporting: UK perspectives. *Accounting Forum* **28**(1): 61–79.

Hutchins MJ, Sutherland JW. 2008. An exploration of measures of social sustainability and their application to supply chain decisions. *Journal of Cleaner Production* **16**(15): 1688–1698.

ISO. 2000. Environmental labels and declarations - General principles (ISO 14020:2000). International Organization for Standardization: Geneva.

ISO. 2004. Environmental management systems - Requirements with guidance for use (ISO 14001:2004). International Organization for Standardization: Geneva.

ISO. 2006. Environmental labels and declarations - Type III environmental declarations - Principles and procedures (ISO 14025:2006). International Organization for Standardization: Geneva.

Jørgensen A, Hauschild M, Jørgensen M, Wangel A. 2009. Relevance and feasibility of social life cycle assessment from a company perspective. *International Journal of Life Cycle Assessment* **14**(3): 204–214.

DOI: 10.1002/csr

Kaenzig J, Friot D, Saadé M, Margni M, Jolliet O. 2011. Using life cycle approaches to enhance the value of corporate environmental disclosures. *Business Strategy and the Environment* **20**(1): 38–54.
Kjellén U. 2000. *Prevention of Accidents through Experience Feedback*. Taylor & Francis: London.
Kolk A. 2008. Sustainability, accountability and corporate governance: exploring multinationals' reporting practices. *Business Strategy and the Environment*, **17**(1): 1–15.
Korhonen J. 2003. Should we measure corporate social responsibility? *Corporate Social Responsibility and Environmental Management* **10**(1): 25–39.
Krajnc D, Glavic P. 2005a. How to compare companies on relevant dimensions of sustainability. *Ecological Economics* **55**(4): 551–563.
Krajnc D, Glavic P. 2005b. A model for integrated assessment of sustainable development. *Resources, Conservation and Recycling* **43**(2): 189–208.
Lamberton G. 2005. Sustainability accounting - a brief history and conceptual framework. *Accounting Forum* **29**(1): 7–26.
Lenzen M, Dey CJ, Murray SA. 2004. Historical accountability and cumulative impacts: the treatment of time in corporate sustainability reporting. *Ecological Economics* **51**(3–4): 237–250.
Line M, Hawley H, Krut R. 2002. The development of global environmental and social reporting. *Corporate Environmental Strategy* **9**(1): 69–78.
McIntosh M. 2003. *Living Corporate Citizenship: Strategic Routes to Socially Responsible Business*. Prentice Hall/Financial Times: London.
Mutel CL, Hellweg S. 2009. Regionalized life cycle assessment: Computational methodology and application to inventory databases. *Environmental Science & Technology* **43**(15): 5797–5803.
Ness B, Urbel-Piirsalu E, Anderberg S, Olsson L. 2007. Categorising tools for sustainability assessment. *Ecological Economics* **60**(3): 498–508.
Park J, Brorson T. 2005. Experiences of and views on third-party assurance of corporate environmental and sustainability reports. *Journal of Cleaner Production* **13**(10–11): 1095–1106.
Pintér L, Hardi P, Bartelmus P. 2005. Sustainable Development Indicators: Proposals for the Way Forward. UNDSD: New York.
Porter, Kramer. 2007. Strategy and society: The link between competitive advantage and corporate social responsibility. *Harvard Business Review* **85**(6): 136–137.
Rasche A. 2009. Toward a model to compare and analyze accountability standards - the case of the UN Global Compact. *Corporate Social Responsibility and Environmental Management* **16**(4): 192–205.
SAI. 2010a. Overview of SA8000. http://www.sa-intl.org/index.cfm?fuseaction=Page.viewPage&pageID=473 [8 December 2010].
SAI. 2010b. SAI Advisory Board. http://www.sa-intl.org/index.cfm?fuseaction=Page.viewPage&pageID=494 [8 December 2010].
SAI. 2010c. Social Accountability International. http://www.sa-intl.org/ [8 December 2010].
Schmiemann M. 2008. Eurostat Statistics in focus 31/2008, Enterprises by size class - overview of SMEs in the EU. Eurostat: Luxembourg.
Searcy C, McCartney D, Karapetrovic S. 2008. Identifying priorities for action in corporate sustainable development indicator programs. *Business Strategy and the Environment* **17**(2): 137–148.
Sethi SP, Emelianova O. 2006. A failed strategy of using voluntary codes of conduct by the global mining industry. *Corporate Governance* **6**(3): 226–238.
Seuring S, Muller M. 2008. From a literature review to a conceptual framework for sustainable supply chain management. *Journal of Cleaner Production* **16**(15): 1699–1710.
SPSS. 2010. SPSS 14.0 for Windows.
Szekely F, Knirsch M. 2005. Responsible leadership and corporate social responsibility: Metrics for sustainable performance. *European Management Journal* **23**(6): 628–647.
Vanclay F. 2006. Principles for social impact assessment: A critical comparison between the international and US documents. *Environmental Impact Assessment Review* **26**(1): 3–14.
Vanclay J, Shortiss J, Aulsebrook S, Gillespie A, Howell B, Johanni R, Maher M, Mitchell K, Stewart M, Yates J. 2010. Customer response to carbon labelling of groceries. *Journal of Consumer Policy* **Special issue**: 1–8.
Waage SA, Geiser K, Irwin F, Weissman AB, Bertolucci MD, Fisk P, Basile G, Cowan S, Cauley H, McPherson A. 2005. Fitting together the building blocks for sustainability: a revised model for integrating ecological, social, and financial factors into business decision-making. *Journal of Cleaner Production* **13**(12): 1145–1163.
Zadek S. 2007. *The Civil Corporation*, rev. ed. Earthscan: London.

DOI: 10.1002/csr

Appendix 5

Bedriftenes produktansvar – en casestudie fra norsk møbelindustri .

Kapittel 18

Bedriftenes produktansvar – en case-studie fra norsk møbelindustri[1]

Annik Magerholm Fet og Christofer Skaar

Introduksjon

Viktige drivkrefter i bedriftenes miljøengasjement har vært en forventning om at dette gir lønnsomhet for bedriften. Det samme gjelder nå for bedriftenes engasjement i å demonstrere sitt samfunnsansvar. Å ta samfunnsansvar kan være lønnsomt ved at det internt i bedriften oppnås bedre arbeidsmiljø, mindre sykefravær, bedre utnyttelse av energi og andre ressurser som bedriften bruker i sin produksjon, samt mindre utslipp og avfall. Det kan også være lønnsomt på den måten at bedriften utvikler bedre bedriftsstrategier og styringssystemer som ivaretar deres samfunnsansvar, og får synliggjort og dokumentert dette overfor sine kunder og interessenter. De vil på denne måten være i en bedre posisjon når det gjelder å vinne kontrakter og være en aktuell samarbeidspartner og leverandør i større nettverk.

Videre kan de ved økt innsikt og forståelse av sitt samfunnsansvar også utvikle strategier som viser samfunnsansvar som omfatter store deler av verdikjeden til produktet, det vil si fra råvareuttak til produksjon, bruk og endelig avhending eller resirkulering av produktet, en såkalt livsløpstenkning.

1 Denne artikkelen er ikke med i den originale utgaven av boka, men er tatt med her for å presentere et viktig CSR-tema fra norsk virkelighet. Temaet for artikkelen tilsier at den burde vært plassert under del 3 «Handlinger og utfordringer», men etter en redaksjonell helhetsvurdering er artikkelen skilt ut som et eget kapittel under delkapitlet «Bidrag fra norsk virkelighet». Artikkelen er tatt inn i den norske utgaven etter tillatelse fra forfatterne og Palgrave Macmillan.

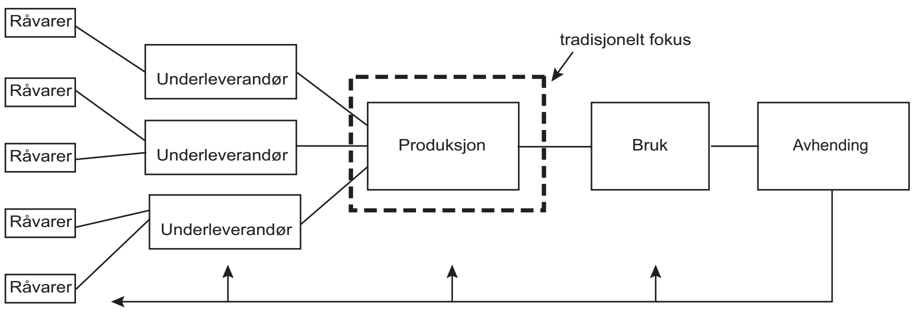
Dette betyr at bedriften kan systematisere arbeidet sitt med samfunnsansvar på to fokusområder; på organisasjonsnivå og produktnivå. Dette er også forankret i Stortingsmelding 10 (2008-2009) om «Næringslivets samfunnsansvar i en global økonomi» der det heter:

> Innholdet i og forståelsen av begrepet samfunnsansvar, er dynamisk. Hvilke tema som er i fokus varierer med virksomhetsområde og forandrer seg over tid. Filantropi, eller gaver til gode formål, har tradisjonelt vært oppfattet som et uttrykk for bedrifters samfunnsansvar. Mange bedrifter forstår fortsatt samfunnsansvar som veldedighet og støtte til lokalsamfunnet. Tendensen er imidlertid at flere oppfatter at kjerneområdet for samfunnsansvar er bedriftens egen virksomhet og leveransekjede.

Samfunnsansvar er hermed et bredt tema som omfatter arbeidsmiljøforhold, etikk, korrupsjon, miljø osv. Som presisert i sitatet er tendensen at det i større grad gjelder virksomheten og leverandørkjeden.

Dette kapitlet handler i hovedsak om hvordan bedrifter kan dokumentere samfunnsansvar – med spesielt fokus på miljøansvar – for hele verdikjeden til sine produkter. Dette blir konkretisert med eksempler fra norsk møbelindustri, som opererer i en global økonomi ved at de har underleverandører og delproduksjon i land som Kina og i Øst-Europa, og salg i markeder i Europa, USA og Japan.

Figur 18.1 illustrerer verdikjeden til et produkt fra råvareuttak via produksjon til bruk og avhending. Tradisjonelt har fokus vært på miljøprestasjoner i den enkelte produksjonsbedrift, mens det nå er mer vanlig å fokusere på CSR-aspekter som dekker hele verdikjeden. I tillegg vil interessentene ofte ha ulike krav til de forskjellige leddene i verdikjeden slik at bedriftene møter større utfordringer i dag enn det de gjorde før.



Figur 18.1 Fra produksjonsfokus til verdikjedefokus fra råvareuttak, produksjon, bruk, avhending og resirkulering

Krav til CSR-dokumentasjon fra ulike interessenter

CSR-informasjon kan ha forskjellig innhold, og det kan kommuniseres på mange måter avhengig av målgruppen for informasjonen. En bedrift vil i første omgang søke å benytte en form for CSR-kommunikasjon som imøtekommer dokumentasjonskrav som stilles av viktige interessenter. Kravene kan komme fra kunder, investorer, forsikringsselskaper, banker, myndigheter og andre interessenter som kan ha en innvirkning på bunnlinjen i selskapet.

En kunde kan være både en privatperson, en virksomhet i en leverandørkjede, en bedrift som sluttbruker eller et myndighetsorgan. Noen privatpersoner etterspør i dag informasjon om miljø- og helsemessige forhold ved de produktene de kjøper, og de ønsker enkel informasjon som det er lett å forholde seg til og forstå. Investorer, forsikringsselskaper og banker stiller gjerne spørsmål om forhold rundt driften av selskapet de skal investere i, om de driver på en samfunnsansvarlig måte, om de kan fremlegge strategier og om de har systemer på plass som sikrer at det unngås brudd på lovverket og andre retningslinjer som bedriften har sluttet seg til. Myndigheter kan ha flere roller, enten som overvåker av lovverket eller som kunde i form av offentlig innkjøper. Som lovvokter vil myndighetene ikke bare etterspørre informasjon om driften av selskapet, men også om produktene som sendes ut på markedet har negative virkninger på for eksempel helse og miljø. Som offentlig innkjøper har myndighetene forpliktelser til å etterspørre dokumentasjon om driftsforhold og styringssystemer hos produsenten, i tillegg til informasjon som gjelder hele livsløpet til produktene. Hvilke type krav som kan eller bør etterspørres, er regulert i en rekke dokumenter som også er premissgivere for hvordan bedrifter må fremstille sin informasjon.

Viktige bakgrunnsdokumenter som setter premissene for CSR-dokumentasjon

Offentlige utredninger, lover og retningslinjer er med på å sette premissene for bedriftenes CSR-fokus. De er også premissgivere på hva som forventes av dokumentasjon når det gjelder bedriftenes CSR-prestasjoner. Norge har en lang tradisjon med et gjeldende og fungerende lovverk som sikrer arbeidstakernes rettigheter gjennom arbeidsmiljøloven (Arbeids- og inkluderingsdepartementet, 2005). Det siste tiåret har det imidlertid vært et økende fokus på miljøkrav, og offentlige dokumenter er blitt utviklet for å lede virksomheter på riktig vei. Blant de viktigste lovene er 1) *Lov om årsregnskap m.v. (regnskapsloven)* (Finansdepartementet, 1998) og 2) *Lov om rett til miljøinformasjon og deltakelse i offentlige beslutningsprosesser av betydning for miljøet (miljøinformasjonsloven)* (Miljøverndepartementet, 2003a).

1. Regnskapsloven

Denne loven dekker i hovedsak økonomiske regnskapsforhold, men den stiller i tillegg krav om at bedrifter skal rapportere om arbeidsmiljø og ytre miljø. §3-3 sier:

> Det skal gis opplysninger om arbeidsmiljøet og en oversikt over iverksatte tiltak som har betydning for arbeidsmiljøet. Det skal opplyses særskilt om skader og ulykker. Regnskapspliktig som i regnskapsåret har sysselsatt minst 5 årsverk, skal i tillegg opplyse særskilt om sykefravær.

Videre sies det i samme paragraf:

> Det skal gis opplysninger om forhold ved virksomheten, herunder dens innsatsfaktorer og produkter, som kan medføre en ikke ubetydelig påvirkning av det ytre miljø. Det skal opplyses hvilke miljøvirkninger de enkelte forhold ved virksomheten gir eller kan gi, samt hvilke tiltak som er eller planlegges iverksatt for å forhindre eller redusere negative miljøvirkninger.

Formålet er å gi et grunnlag for å vurdere selskapet i en miljømessig sammenheng og å gi et bilde av dets miljømessige forpliktelser og utviklingsmuligheter.

2. Miljøinformasjonsloven

Denne loven har til formål å sikre allmennheten tilgang til miljøinformasjon. Med miljøinformasjon menes faktiske opplysninger og vurderinger om miljøet og faktorer som påvirker eller kan påvirke miljøet, for eksempel forhold ved drift av en virksomhet eller produkters egenskaper og innhold og deres effekt på miljøet. I denne loven står det at bestemmelsene gjelder «... annen offentlig eller privat virksomhet, herunder næringsvirksomhet og annen organisert virksomhet».

Denne loven gir dermed forbrukeren makt til å påvirke næringsvirksomhet og til å kunne fremskaffe informasjon om produkters miljøegenskaper.

Andre viktige offentlige dokumenter som er med på å styre utviklingen er 3) *Miljøledelse i staten* (Miljøverndepartementet, 2003b); 4) *Sammen for et giftfritt miljø* (St.meld. nr. 14, 2006-2007); 5) *Miljø- og samfunnsansvar i offentlige anskaffelser* (Miljøverndepartementet, Fornyings- og administrasjonsdepartementet, Barne- og likestillingsdepartementet, 2007) og 6) *Næringslivets samfunnsansvar i en global økonom*i (St.meld. nr. 10, 2008-2009).

3. Miljøledelse i staten

Dette er en veileder med mål å gi statlige virksomheter et godt grunnlag for å integrere miljøhensyn i egen virksomhet. Dette gjøres både med tanke på å integrere samfunnsansvaret for miljø i eksisterende styringssystemer, i ledelse og organisasjon, samt å styrke kompetanse på de mest sentrale miljøproblemene. Veilederen har fokus på hvordan statlige virksomheter skal arbeide med miljøledelse og ideer til tiltak. Noen av tiltakene er rettet mot bærekraftig produksjon og forbruk, og hvordan statlig sektor kan påvirke næringslivet i slike retninger. Dette innebærer at statlig sektor stiller krav til næringslivet.

4. Sammen for et giftfritt miljø

Målet med denne stortingsmeldingen er å legge til rette for et giftfritt miljø og hindre at kjemikalier skader helse og miljø. Føre-var-prinsippet og substitusjon av farlige kjemikalier med mindre farlige er viktige prinsipper i stortingsmeldingen. Kjemikalier benyttes i produksjonsbedrifter, og arbeidstakere eksponeres for disse. Tilsvarende blir forbrukere eksponert for helse- og miljøfarlige kjemikalier i de produktene de kjøper. Dette betyr at produsenter må ha kjennskap til de kjemikaliene og giftige stoffene som benyttes og som inngår i de produktene de sender ut på markedet, samt effekten av disse stoffene på helse og på ytre miljø.

5. Miljø- og samfunnsansvar i offentlige anskaffelser

Dette er en handlingsplan (2007-2010) for miljø- og samfunnsansvar i offentlige anskaffelser. Overordnede mål er at anskaffelser i offentlig sektor bør skje med et minimum av miljøbelastning og med respekt for grunnleggende arbeider- og menneskerettigheter. Videre skal miljø, etiske og sosiale hensyn være et redskap som bidrar til en effektiv offentlig sektor og et konkurransedyktig næringsliv. De overordnede prinsippene er at varer og tjenester skal velges på bakgrunn av livsløpskostnader, kvalitet og miljøegenskaper. Kriterier som energieffektivitet, lavt innhold av helse- og miljøfarlige kjemikalier, lave forurensende utslipp og lavt ressursforbruk, skal prioriteres ved kjøp av varer og tjenester.

6. Næringslivets samfunnsansvar i en global økonomi

Målet med denne stortingsmeldingen er å bidra til en klargjøring av myndighetenes og næringslivets roller og samfunnsansvar, rekkevidden av bedrifters ansvar, samt samfunnsansvar i leveransekjeden. Næringslivets internasjonale engasjement med tilhørende utfordringer og dilemmaer belyses, og det gis en oversikt over ulike virkemidler for å styrke næringslivets samfunnsansvar. Partnerskap mellom myndigheter, næringsliv og ikke-statlige organisasjoner (NGOer[2]) vektlegges. Meldingen tar også sikte på å bidra til å styrke internasjo-

2 NGO er en forkortelse for Non-Governmental Organisation. En NGO er en ikke-statlig organisasjon som arbeider uten økonomisk vinning som mål. Eksempler på slike organisasjoner er Amnesty International, Greenpeace, Transparency International, Røde Kors og Redd Barna.

nale rammeverk for å øke minimumsstandardene for samfunnsansvar. I Stortingsmeldingen heter det:

> Norge vil være en pådriver i arbeidet som pågår i FN og OECD for retningslinjer og prosesser som fremmer samfunnsansvar.

Det påpekes videre at

> bedrifter som tar et aktivt samfunnsansvar vil styrke sin konkurransekraft og sitt omdømme, mens de som neglisjerer samfunnsansvar kan oppleve negative konsekvenser for kapitaltilgang, verdiskaping og rekruttering. Samfunnsansvar kan samtidig påføre bedriftene nye kostnader, særlig dersom de ikke allerede bedriver et systematisk arbeid med dette.

Konsekvenser av offentlige dokumenter for produsentbedrifter

Disse dokumentene viser at myndighetenes fokus har skiftet fra et typisk ledelsesfokus i den første meldingen, til et sterkere fokus på varer og tjenester med en CSR-profil. Utfordringen for næringslivet er derfor å kunne være i stand til å fremskaffe den nødvendige grunnlagsinformasjonen slik at det offentlige kan velge produkter ut fra kriterier som livsløpskostnader, kvalitet og miljøegenskaper, og god etisk og sosial profil på produktene.

Selv om Norge og de andre skandinaviske landene har vært i fremste rekke når det gjelder å implementere lovverk og retningslinjer som stiller strengere krav til industrien enn i andre land og deler av verden, finnes det likevel internasjonale rammeverk som støtter den samme filosofien. Et eksempel er EUs håndbok «Buying green! A handbook on environmental public procurement.» (European Commission 2004). Budskapet i denne boken er at innkjøpsmakt kan benyttes som et viktig bidrag på veien mot bærekraftig utvikling. *Grønne innkjøpskrav* dekker områder som energieffektivitet i IT-utstyr og bygg, resirkulert papir, elektriske biler, energi fra fornybare kilder og miljøvennlig offentlig transport. Grønne offentlige innkjøp gjelder også å sette eksempler og dermed bidra til at industrien utvikler mer miljøvennlig teknologi. I tillegg vil livsløpsanalyser og vekt på livsløpskostnader sette fokus på miljøeffekter fra hele verdikjeden til et produkt.

Andre krav og andre interessenter

CSR omfatter for eksempel barnearbeid, korrupsjon, fattigdomsbekjempelse og hvordan bedrifter håndterer dette, samt hvordan de er i stand til å dokumenter sine prestasjoner på dette området. En rekke internasjonale retningslinjer og konvensjoner setter rammen for hva som bør dokumenteres og hva dokumentasjonen skal omfatte. Global Compact (Global Compact, 2009) og

GRI (Global Reporting Initiative, 2009) er eksempler på dokumenter som setter de overordnende rammene. Produktansvar er ett av prinsippene som nevnes under GRI, både under kategoriene miljø og sosialt ansvar. Videre foreslår GRI indikatorer om produktets helsemessige effekter som én mulig måte å informere om sosialt ansvar på i forhold til produkter.

Ovenfor er det vist en gjennomgang av krav fra myndighetene som virksomheter må forholde seg til, for eksempel ved offentlige anbud. En tilsvarende systematisk oversikt av krav fra den private sektoren og andre interessenter er det vanskelig å finne. Trenden er imidlertid at større virksomheter integrerer CSR-aspekter som krav i sine innkjøpsstrategier og det må mindre bedrifter i verdikjeden forholde seg til, noe som igjen fører til en økt bevissthet og kunnskap i verdikjeden.

Fokuset videre i dette kapitlet er i hovedsak miljø- og helsemessige aspekter som er knyttet til produkter, samt hvilke metoder som bedriften kan benytte for å dokumentere sine CSR-prestasjoner som er av relevans for produktinformasjon. Mange bedrifter mener også at bedre produktkunnskap gir konkurransefordeler i markedet.

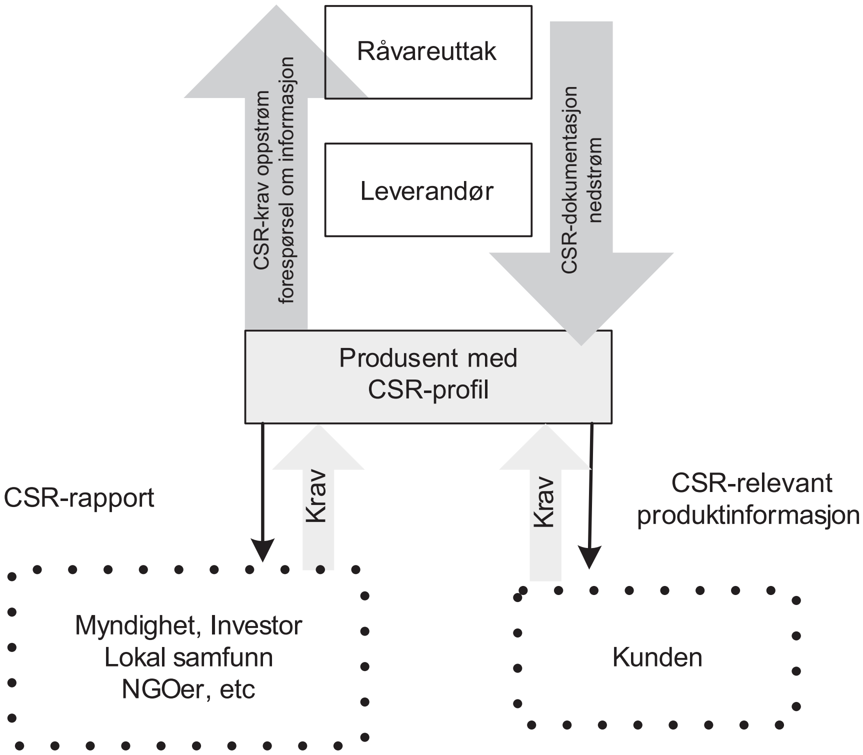
Dokumentasjon av miljø- og samfunnsansvar

Oversikten ovenfor viser at det er et økende behov for å kunne dokumentere miljø- og samfunnsansvar. Dokumentene som det er referert til, er ikke alltid like klare med hensyn til hvilke typer krav som skal stilles, så spørsmålet er da: Hvordan skal bedrifter dokumentere måtene de imøtekommer kravene til miljø- og samfunnsansvar på?

Det kan i hovedsak gjøres på to måter. Enten i form av ledelsesrelaterte forhold (strategier, styringssystemer, rapportering, engasjement i veldedighet o.l.) eller i form av produktrelatert informasjon (miljøvennlige designprinsipper, produktmerker, emballasjevalg o.l.). I begge tilfeller er det aktuelt å tenke langs hele verdikjeden, se Figur 18.1. Figur 18.2 tar utgangspunkt i en produsent med en uttalt CSR-profil. Det betyr at han har en forpliktelse til å gi interessenter informasjon om CSR-prestasjoner, for eksempel i årsmeldingen og stille relevant informasjon tilgjengelig til kunden i form av for eksempel produktdeklarasjoner. Dette innebærer at han også har en forpliktelse til å innhente CSR-relevant informasjon oppstrøms i verdikjeden.

Informasjon som skal ut til kunden kan omfatte forhold både *oppstrøms*- og *nedstrøms* i verdikjeden. Oppstrøms i verdikjeden kan informasjonen gjelde materialvalg, produksjonsmetoder og arbeidsmiljøforhold. Nedstrøms i verdikjeden kan informasjonen vedrøre bruk og avhending av produkter og potensielle helseeffekter ved bruk av produktet.

For å utarbeide produktinformasjon må det innhentes informasjon fra leverandører og underleverandører. Dette bidrar til at disse må sette fokus på ytre miljø og arbeidsmiljø for å fremskaffe informasjonen som etterspørres.



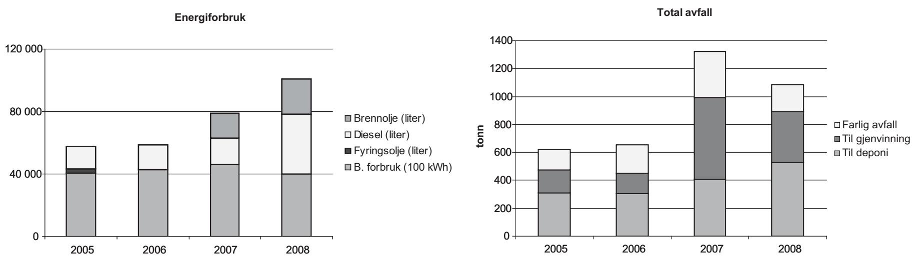
Figur 18.2 Illustrasjon av verdikjeden og krav fra ulike interessenter

For å kunne sette opp et totalt CSR-regnskap for produktet er det behov for å se på produksjonsforholdene og materialvalgene langs hele verdikjeden. Det bør også vurderes hvilke CSR-aspekter det skal lages regnskap for. For å illustrere hvordan bedrifter kan ivareta sitt produktansvar er det i første omgang gjort rede for fremgangsmåten ved å dokumentere miljøegenskaper og miljøprestasjoner. I siste del av kapitlet reflekteres det over hvordan andre CSR-aspekter kan integreres og presenteres i produktinformasjonen.

Miljøregnskap ved produksjon

Ifølge regnskapsloven skal det i årsmeldingen gis informasjon om

1. type og mengde energi og råvarer som forbrukes
2. type og mengde forurensning som slippes ut, herunder støy, støv og vibrasjoner
3. type og mengde avfall som genereres eller besittes, for eksempel nedgravde masser, åpne og lukkede deponier, avsetninger i vassdrag eller sjø osv.
4. aktiviteters ulykkesrisiko
5. miljøbelastning knyttet til transport



Figur 18.3 Eksempler på miljøregnskap fra en virksomhet, her energiforbruk og avfall

Bedrifter som tar dette seriøst, har som regel innført miljøstyring i henhold til ISO 14001 (International Organization for Standardization, 2004a) eller EMAS (Miljøverndepartementet, 2004). Ved starten av 2008 var det 154 572 bedrifter med ISO 14001-sertifikater verden over, fordelt på 148 land. Det var en stigning på 21 % i løpet av 2007 (International Organization for Standardization, 2007). Ved utgangen av 2007 var det 618 ISO 14001-sertifikater i Norge (International Organization for Standardization, 2007) og 23 EMAS-godkjenninger (Brønnøysundregistrene, 2009). Som en del av miljøstyringssystemet har disse bedriftene etablerte prosedyrer og rutiner internt i virksomheten som sikrer registreringer og oppfølging på miljøaspektene, som nevnt ovenfor. Eksempel på fremstilling av miljøregnskap for en produksjonsbedrift er vist i Figur 18.3. Den viser et energiregnskap og et avfallsregnskap for en periode på fire år for et middels stort norsk skipsverft.

I ISO 14001-standarden, som kom i ny utgave i 2004, er det økt fokus på produkt.

I siste del av punkt 4.3.1 Miljøaspekter står det: «Organisasjonen skal etablere og holde ved like prosedyrer for å identifisere miljøaspektene forbundet med dens aktiviteter, produkter *og* tjenester…». Her er altså «eller» fra den første standarden byttet ut med «og». Dette betyr at fokuset på miljøaspekter som er forbundet med produkter ble forsterket, og at bedrifter som innfører miljøstyring i henhold til ISO 14001 også påtar seg en forpliktelse til å fremskaffe miljøinformasjon for sine produkter, og at de har en forpliktelse til å gi denne type informasjon til sine kunder. Dette har resultert i at mange bedrifter derfor har kartlagt sine produkters miljøaspekter.

Miljøregnskap – produkter

I henhold til kravene i regnskapsloven skal bedrifter som tilvirker produkter også dokumentere:

a) type og mengde helse- og miljøfarlige kjemikalier som inngår i produktene
b) type og mengde avfall som oppstår når produktene kasseres
c) miljøbelastning ved bruk av produktene

Figur 18.4 Eksempler på miljøinformasjon på produkter

Videre vil det være lettere å oppfylle substitusjonsplikten ved at produsentene har oversikt over materialer i produktet.

Miljøinformasjon for produkter kan være i form av miljødeklarasjoner (International Organization for Standardization, 2006a) eller miljømerker, og kan som vist i figur 18.4, fremstilles på mange måter. Noen av de mest kjente merkeordningene er Svanemerket (Stiftelsen Miljømerking, 2009), Ø-merket (Debio, 2009) og resirkuleringsmerket der Grüne Punkt (Der Grüne Punkt, 2009).

Miljømerker og miljødeklarasjoner

Fremstilling av miljøaspekter til produkter kan gjøres ved å ta i bruk ulike typer standarder, for eksempel ISO-standardene:

- ISO 14020 Miljømerker og deklarasjoner – generelle prinsipper (International Organization for Standardization, 2002).
- ISO 14021 Miljømerker og deklarasjoner, Miljømerking type II: Egendeklarerte miljøpåstander (International Organization for Standardization, 2001a).
- ISO 14024 Miljømerker og deklarasjoner, Miljømerking type I: Prinsipper og prosedyrer (International Organization for Standardization, 2000).
- ISO 14025 Miljømerker og deklarasjoner, Miljødeklarasjoner type III: Prinsipper og prosedyrer (International Organization for Standardization, 2006a).

Type I-merker kan karakteriseres som offisielle merker, for eksempel Svanemerket (Stiftelsen Miljømerking, 2009) som blant annet er basert på en livsløpsvurdering av produktets påvirkning innen ulike miljøkategorier, eller FSC (Forest Stewardship Council), som sier noe om ett av produktets miljøaspekter i en eller flere av produktets livsfaser (Forest Stewardship Council, 2009). Type I-miljømerker må verifiseres av en uavhengig tredje part for å ha noen verdi.

En miljødeklarasjon gir en kvantifisert oversikt over ressurs- og energistrømmer gjennom et produkts livsløp, samt en oversikt over hvilke miljøpåvirkninger disse strømmene medfører (Fet og Skaar, 2006). Forhåndsbestemte data- og miljøpåvirkningskategorier avgjør hvilken informasjon som skal hentes inn til en miljødeklarasjon. Det skilles mellom Type II: Egengodkjente og Type III: Uavhengig verifiserte. En egengodkjent miljødeklarasjon utarbeides av produsenten selv (eller av innleid konsulenthjelp), og det er ingen uavhengig tredjepart som gransker miljødeklarasjonen. Type III-krav består av både å gjennomføre en livsløpsanalyse (Life Cycle Assessment (LCA) av produktet i henhold til ISO 14040-standarder, og at en tredjepart må verifisere deklarasjonen. Informasjonen skal muliggjøre en sammenligning mellom produkter med samme funksjon. Utover dette finnes det ingen spesielle krav til funksjonen eller prestasjonen til produktet for å få en slik deklarasjon.

Flere betegnelser brukes for Type III-programmer og tilhørende miljødeklarasjoner på produkter, for eksempel EcoLeaf (Japan Environmental Management Association for Industry, JEMAI, 2002), økoprofil (Tillmann, 1998), miljødeklarasjon av produkt (Korea Eco-Products Institute, 2009), miljørettet profil, dataark (Row og Wieler, 2003), miljørettet produktdeklarasjon (Swedish Industrial Research Institutes' Initiative, SIRII, 2002) og Næringslivets stiftelse for miljødeklarasjoner, Norge (2002). Her brukes Type III Environmental Product Declaration (EPD) for å referere til miljødeklarasjoner som i praksis er et kortfattet dokument som oppsummerer miljøprofilen til en komponent, et ferdig produkt eller en tjeneste på en standardisert og objektiv måte. Forkortelsen EPD brukes både i norsk og internasjonal sammenheng.

Regler for produktkategorier og utvikling av slike

Regler for produktkategorier (Product Category Rules, PCR) er grunnlaget for å utvikle EPDer i henhold til ISO 14025 (Fet et al., 2008). En produktkategori er en gruppe produkter med samme funksjon. Målet med PCR er å identifisere funksjonskarakteristikker for produktet, definere kriteriene som skal brukes i LCA-studiet av produkter tilhørende samme kategori, og spesifisere informasjonen som må rapporteres i EPD, herunder parametre for rapportering og hvordan de nødvendige dataene for EPDen skal hentes inn og fremstilles.

Innholdet i et PCR-dokument skal i henhold til ISO 14025 være:

1. Generell informasjon.
2. Definisjon av type produktkategori.

3. LCA-basert informasjon, herunder definisjon av funksjonell enhet, systembegrensninger, beskrivelse av data, kriterier for inn- og utstrømmer, krav til datakvalitet og enheter.
4. Inventaranalyse, herunder samling av data og kalkuleringsprosedyrer, kriterier til «cut off» og regler for allokering.
5. Kategorier for miljøeffekter.
6. Parametere og kilder til data for den underliggende LCA-rapporten .
7. Annen informasjon, for eksempel annen produktinformasjon og andre parametere som skal deklareres i EPD, informasjon om underliggende LCA-data, andre instruksjoner om datasamling for utviklingen av EPD og annen frivillig informasjon.
8. Innhold i miljødeklarasjonen (EPD), herunder generell informasjon som skal deklareres og parametere som skal deklareres.

PCR-dokumenter utvikles i samarbeid mellom bedrifter som representeres en bransje og kompetansemiljøer som er godkjent av Næringslivets stiftelse for miljødeklarasjoner. Ved manglende PCR for en produktgruppe kan det settes i gang et program for å utvikle nye PCRer. Dokumentet legges ut på høring for internasjonale uttalelser før endelig godkjenning og registrering under det nasjonale EPD-programmet.

EPD – format og innhold

En EPD skal inneholde en del standardisert informasjon om produktet, produsent og metoder som er benyttet ved fremskaffing av datamateriale. Dette er informasjon som:

- Produsentens navn og adresse;
- Produktets identifikasjon ved navn (inkl. f. eks. produksjonskoden) og en enkel visuell representasjon av produktet og en spesifisering av komponentene til produktet;
- Beskrivelse av produktets bruksområde, samt den funksjonelle enheten som dataene relateres til;
- Navn og adresse til programoperatøren, logo og henvisning til hjemmeside, dato for utstedelse av deklarasjonen og hvor lenge den er gyldig;
- Informasjon om deklarasjonen er komplett eller modulær;
- PCR- identifikasjonen;
- Informasjon om at miljødeklarasjoner fra andre programmer muligens ikke er sammenlignbare (ISO 14025);
- Produksjonssted, produsent eller gruppe av produsenter som LCA-resultatene representerer, og referanser til hvor forklaringsmaterialet kan finnes;
- Et diagram over de ulike stadiene i livsløpet som er inkludert i LCA, delt inn i produksjon, bruk og avhending og systembegrensninger;

Det vesentlige innholdet i en EPD er imidlertid miljødokumentasjonen for produktet. EPDen inneholder en spesifikasjon av produktets komponenter angitt i materialtyper.

Videre skal det fremlegges hvilke mengder av ressurser som er brukt for å fremstille produktet, herunder bruk av

- materialressurser
- ikke-fornybar primærenergi, delt inn i fossil olje, naturgass, kull og uran
- fornybar primærenergi, delt inn i vannkraft, vindkraft, solenergi og biomasse
- vann

I tillegg skal det oppgis mengder og typer avfall som genereres ved fremstilling av produktet. Materialinformasjonen skal være basert på livsløpsanalyser, og resultatene fra analysen skal presenteres i henhold til effektkategoriene i venstre kolonne i tabell 18.1.

Effektkategori	**Forklaring**
Klimaendring (drivhusgasser)	Utslipp av drivhusgasser (uttrykt som summen av potensiell global oppvarming (global warming potential, GWP) i kg CO_2-ekvivalenter, 100 år).
Reduksjon av det stratosfæriske ozonlaget	Utslipp av ozonreduserende gasser (uttrykt som summen av ozonreduserende potensial (ozone-depleting potential, ODP) i kg CFC 11-ekvivalenter, 20 år).
Forsuring av land- og vannkilder	Utslipp av forsurende gasser (uttrykt som summen av forsurende gasser (acidifying potential, AP) i kg SO_2-ekvivalenter).
Eutrofiering (overgjødsling)	Utslipp av stoffer som bidrar til eutrofieringspotensial (uttrykt som summen av næringspotensial (nutrition potential, NP) i kg PO_4-ekvivalenter).
Dannelse av troposfærisk ozon (fotokjemiske oksidanter)	Utslipp av gasser som bidrar til dannelsen av ozon på bakkenivå (uttrykt som summen av ozondannende potensial (ozone creating potential, POPC) i kg C_2H_4-ekvivalenter).
Tungmetaller	Utslipp av tungmetaller (uttrykt som summen av tungmetallutslipp) i Pb-ekvivalenter.

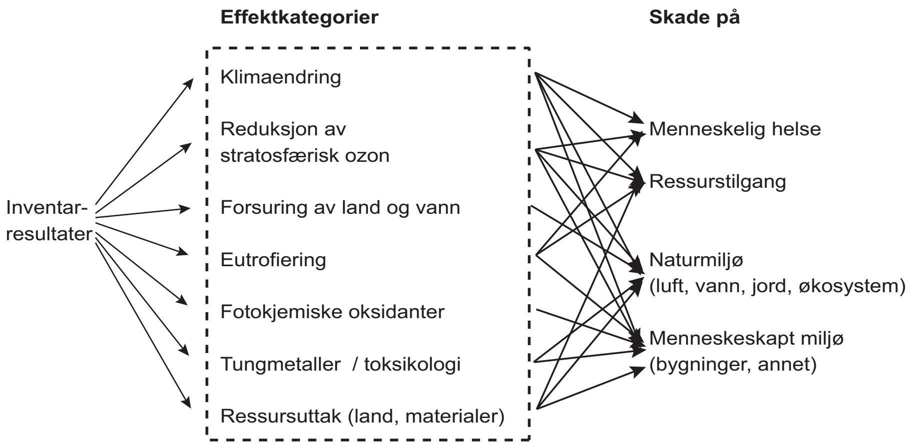
Metodikken for systematiseringen av bidragene til de ulike effektkategoriene er i tråd med LCA-metodikken i ISO 14040- og ISO 14044-standardene (International Organization for Standardization 2006d og 2006e) der stoffene først klassifiseres i forhold til den effektkategorien de bidrar til, og videre at de karakteriseres (vektes) i forhold til deres relative bidrag innen en gitt effektkategori. For miljøpåvirkningskategorien *klimaendring* er *globalt oppvarmingspotensial* for eksempel valgt som parameter. Parameterverdien er summen av alle utslipp som bidrar til global oppvarming, målt i CO_2-ekvivalenter. Utslipp av for eksempel 1 kg metan tilsvarer 23 kg CO_2-ekvivalenter, siden metan har 23 ganger så stort bidrag til global oppvarming som CO_2.

De ulike effektene vil dessuten ha en potensiell skade på menneskelig helse, ressursgrunnlaget, naturmiljøet og det menneskeskapte miljøet. Dette er illustrert i figur 18.5, som viser noen av de viktigste effektkategoriene.

Resultatene fra livsløpsanalysen skal presenteres ved hjelp av diagrammer i EPDen, og de skal fremstille hvilke materialer som bidrar til de ulike effektkategoriene og hvor i livsløpet påvirkningen er størst. Det er også mulig å fremstille utdrag av effektkategoriene, for eksempel et CO_2-regnskap i forhold til produktets funksjonelle enhet.

I tillegg kan EPD også inneholde informasjon om service og vedlikehold, hva brukeren av produktet kan gjøre for ytterligere å redusere produktets innvirkning på miljøet, informasjon om gjenbruk og resirkulering, så vel som retningslinjer for demontering og avfallshåndtering. Informasjon om miljørettet arbeid (for eksempel miljøstyring) hos importør, produsent og forhandler, kan også med fordel inkluderes. Alle EPDer i en produktkategori skal ha samme format og inneholde de samme dataene som identifiseres i den PCR som programoperatøren legger frem. Dersom EPDen er en moduldeklarasjon (for eksempel «vugge-til-port»- eller «port-til-port»-EPD), skal dette presiseres klart i EPDen.

Det er også mulig å inkludere ytterligere informasjon i en EPD, for eksempel informasjon om helsemessige eksponering (stråling, avgasser og lignende) i bruksfasen til produktet eller kjemikalieeksponering i produksjonsfasen. Dette skal det da være åpnet for i PCR-dokumentet. En EPD med informasjon om dette vil etter hvert kunne utvides til en CSR-deklarasjon for produktet.



Figur 18.5 Generell struktur i livsløpsanalyser (LCA) og aggregering av måledata (tilpasset fra Jolliet et al., 2004)

Verifisering av EPD

For en Type III EPD stilles det klare krav til granskning av en uavhengig tredjepart EPD-verifisør. Det betyr at kvaliteten, nøyaktigheten og hvor komplette dataene er, skal verifiseres. I tillegg må EPDens overensstemmelsen med PCRen vurderes. Verifiseringen av LCA-data i EPDen må minst kunne bekrefte overensstemmelse med gjeldende PCR. Programoperatørens (i Norge er dette Næringslivets stiftelse for miljødeklarasjoner) oppgaver er å forberede, vedlikeholde og kommunisere programinstruksjonene, publisere PCRene og EPDene, etablere oversiktsprosedyrer og overvåke relaterte Type III-programmer.

Nytteverdi og utfordringer ved utvikling av EPDer

EPDer gir som sagt kvantifisert informasjon om miljøaspekter ved produkter, og er på den måten et redskap til å bringe miljøinformasjonen ut til kunden, som vist i figur 18.2. Kunden og den offentlige innkjøperen kan benytte EPDen som grunnlag til å velge det produktet med lavest bidrag til de forskjellige parametrene og effektkategorier som er presentert i tabell 18.1. Nytteverdien av en EPD er derfor stor der det stilles krav til miljødokumentasjon ved innkjøp. Informasjonen som er presentert, gjør det mulig å velge det produktet som for eksempel har det laveste bidraget til drivhuseffekten. En av de sektorene som har hatt spesielt fokus på miljøkrav ved innkjøp av produkter, er byggsektoren, spesielt offentlige bygg, der det stilles krav til byggematerialer og til inventar. For disse sektorene er det per i dag utviklet flere PCR- og EPDer, for eksempel for bygningsplater, vinduer, sittemøbler, liggemøbler og bord.

Utfordringer ved datainnhenting

En ferdig og velbegrunnet EPD vil fungere som et godt grunnlag ved valg av produkter. Den største utfordringen ligger imidlertid i innhenting av datagrunnlaget. En produsent har i dag en rekke underleverandører i en verdikjede som kan være ganske global. Erfaringer viser at det kan være svært forskjellig kvalitet på de dataene som blir stilt til rådighet. Det kan også være vanskelig å fremskaffe data for de ulike delkomponentene i et produkt, og det blir derfor ulike systemgrenser (deler av livsløpet) som benyttes for de ulike delkomponentene. I noen tilfeller viser det seg også umulig å fremskaffe spesifikke data, og det må hentes tall fra litteratur eller databaser. Dette er et tidkrevende arbeid, som spesielt små og mellomstore bedrifter ikke har kapasitet til. I de fleste tilfeller er det også behov for noe kompetanse om miljøeffekter når dataene hentes inn, samtidig som det må stilles spisskompetanse til rådighet for å analysere dataene og deres effekt på de forskjellige miljøkategoriene. Små og mellomstore bedrifter har som regel ikke de kompetanseressursene som trengs internt i virksomheten. For at de skal kunne imøtekomme de krav som bedriftene stilles overfor når det gjelder produktdokumentasjon, må de enten hente inn ekstern kompetanse eller skaffe tilgjengelig, egnet analyseverktøy.

Begge utfordringene har vært utgangspunktet for norsk møbelindustri som har lansert et program der de ønsker EPDer for 80 % av norske møbler. De fleste norske møbelbedrifter er små bedrifter, og har derfor behov for enkle hjelpemidler og verktøy for å fremskaffe nødvendig informasjon. Samtidig må informasjonen være av en slik kvalitet at resultatene som blir presentert, er etterprøvbare og representerer den bransjen de skal benyttes i.

DATSUPI – et modulbasert verktøy til hjelp for produktdokumentasjon

Analyseverktøyet «Data Assisted Tool for Sustainability Product Information – DATSUPI» er et dataassistert verktøy for bærekraftig produktinformasjon. Det er blitt utviklet for den norske møbelindustrien. Formålet med DATSUPI er å hjelpe bedrifter til å møte krav om CSR-dokumentasjon for produkter i et internasjonalt marked. I DATSUPI omfatter dette informasjon om ytre miljø,

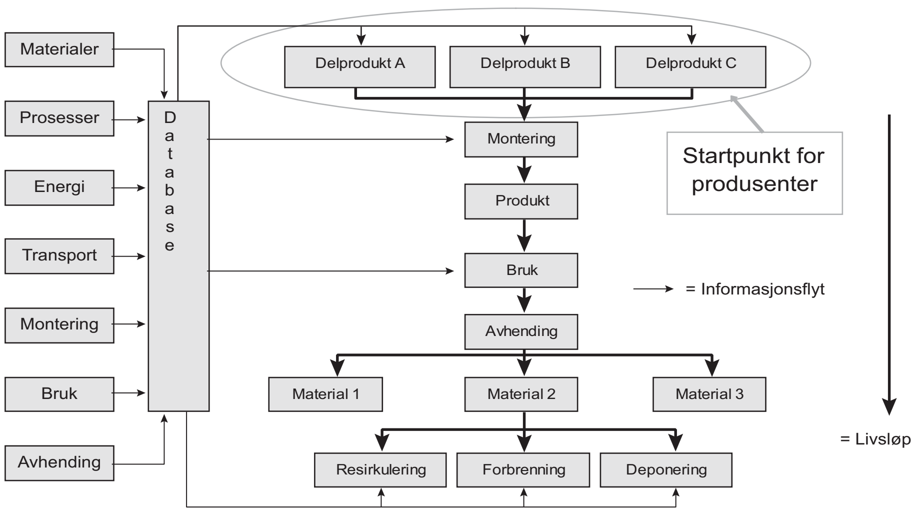
Figur 18.6 En stol kan bestå av modulene ramme, sete og rygg

arbeidsmiljø og potensiell eksponering av stoffer i bruksfasen til produkter. DATSUPI blir i hovedsak benyttet til å fremstille EPDer, men det kan også benyttes ved utvikling av nye produkter. Informasjon om enkelte moduler og materialer kan benyttes i nye produkter, og på denne måten vil produktutviklere allerede på skissebordet kunne gjøre prioriteringer som er basert på vurdering av miljøbelastninger.

DATSUPI kan på denne måten frembringe informasjon som er relevant for interne interessenter (produktutviklere, innkjøpere og selgere) og eksterne interessenter (kunder, myndigheter og leverandører). Verktøyet er utviklet i samarbeid mellom norske møbelbedrifter, norske kompetansemiljøer og bransjeforeningen Norsk Industri – møbel. Møbelbedriftene blir i økende grad spurt spesielt om miljødokumentasjon på produkter, spesielt ved offentlige innkjøp. De ser det som strategisk viktig å kunne gi sine interessenter denne type informasjon, men har selv ikke kapasitet og kompetanse til å gjøre kompliserte LCA-analyser: Derfor har de i samarbeid med forskere fra ulike miljøer, og med støtte fra Norges Forskningsråd, utviklet DATSUPI-verktøyet. En forutsetning for å kunne benytte DATSUPI er at det eksisterer en PCR for aktuell produkttype, og at det er forhåndsgenerert en database med LCA-data for aktuelle materialtyper som inngår i de møblene som skal analyseres. Metodikken er imidlertid generell, og kan brukes i annen vareproduserende industri, da med andre databaser.

Figur 18.6 viser en enkel stol som består av tre moduler, eller delprodukter. Hver av disse kan igjen bestå av flere materialer, som plast, tekstil, metall eller seteputen kan ha et ekstra trekk, som vist i det høyre bildet.

Figur 18.7 viser prinsippene for hvordan DATSUPI brukes for å fremskaffe informasjon om hele produktets livsløp basert på en produktspesifikasjon. Brukeren definerer et produkt, som her består av delene ramme, sete

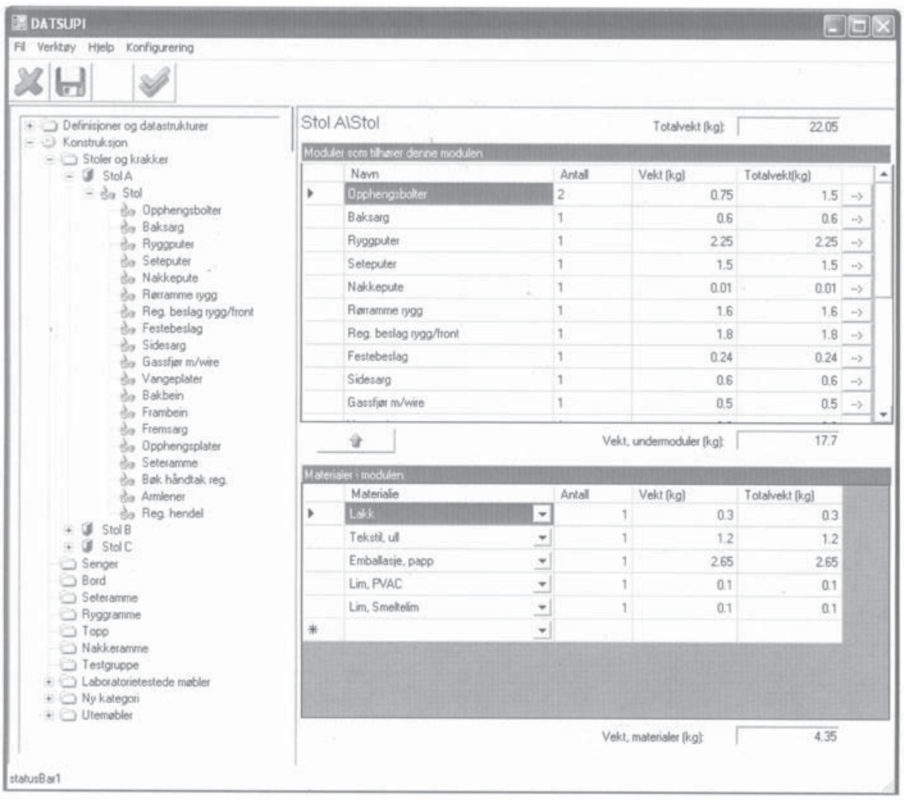


Figur 18.7 Informasjonsflyt i DATSUPI med utgangspunkt i en produktdefinisjon

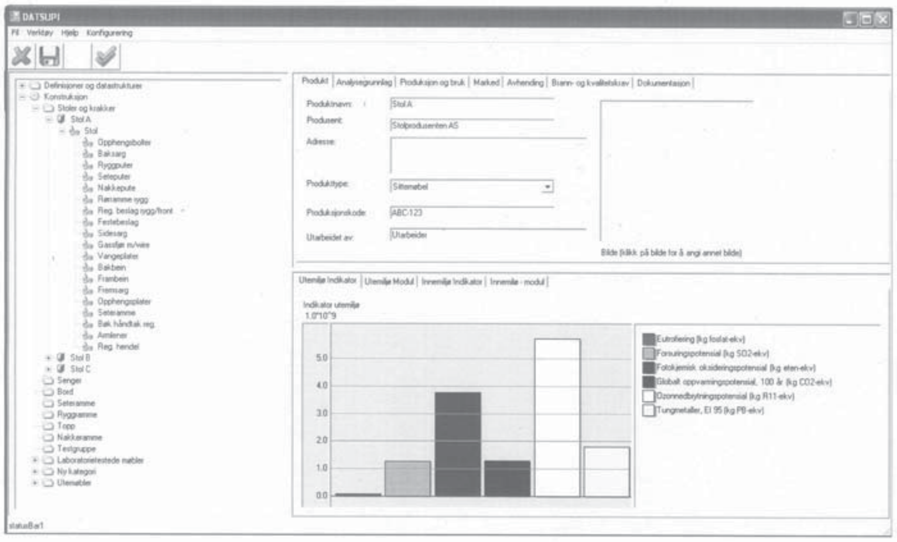
og rygg. Når produktdefinisjonen er gjort, vil DATSUPI hente informasjon fra databasen som dekker materialenes livsløp. Denne databasen er forhåndsdefinert og inneholder LCA-data for de mest aktuelle materialene i norske møbler.

For å få ut produktinformasjon for et møbel fra DATSUPI, må møbelet først defineres i DATSUPI. Dette gjøres ved å spesifisere de materialtyper og -mengder som inngår i møbelet, samt produksjonstid for møbelet hos møbelprodusenten. I tillegg er det mulig å spesifisere markedsområde og velge avhendingsscenario. Spesifiseringen kan gjøres enten for et helt produkt eller for de enkelte modulene som produktet består av, for så å se på det sammensatte produktet. Figur 18.8 viser hvordan en stol kan defineres i hovedmenyen DATSUPI. Her velges forhåndsdefinerte materialer fra nedtrekksmenyer, der brukeren må spesifisere antall og mengde for hvert materiale.

En modul i DATSUPI kan, som vist i figur 8, være en seteramme, et bakbein, en setepute eller lignende. Siden DATSUPI er modulbasert, kan hver enkelt modul brukes om igjen for å analysere andre møbler i DATSUPI. Enkeltmoduler kan også analyseres for seg selv. Dette gjør det mulig for en produsent å forbedre hver enkelt del av et møbel for seg selv, i tillegg til møbelet som helhet.



Figur 18.8 DATSUPIs hovedmeny: Produktdefinisjon



Figur 18.9 DATSUPI-resultater for ytre miljø

Figur 18.9 viser hvordan produktinformasjon fremstilles i DATSUPI, i dette tilfellet ved de seks effektkategoriene, se tabell 18.1.

Grunnlagsinformasjonen i DATSUPI er databasen som inneholder informasjon om ytre miljø. I tillegg vil databasen bli utvidet med informasjon om arbeidsmiljø i produksjonsfasen og potensielle emisjoner med effekt på innemiljø i bruksfasen. Bruksområdet til DATSUPI er å generere EPDer og analysere CSR-profilen (miljø, arbeidsmiljø og potensielle påvirkninger i bruksfasen) til nye produkter i en tidlig produktutviklingsfase.

Generering av EPD

LCA-dataene er generert ved hjelp av analyseverktøyet GaBi (PE International, 2009) og grunnlaget for analysen er innsamlede data, databaser i GaBi og åpne databaser (European Commission, 2009). Hvis produktets levetid er spesifisert, kan DATSUPI automatisk generere EPDen i henhold til ISO 14025.

Figur 18.10 viser forsiden av en EPD for en stol. På denne siden er standardisert informasjon om produktet, produsent, levetid og garantitid samt produktspesifikasjon i tabellformat. Denne inkluderer også informasjon om systemgrensene som gjelder for hvert av materialene. På side 2 i EPDen informeres det om forbruk av naturressurser (resirkulerbare og ikke-resirkulerbare) og energiforbruk fordelt på ulike energibærere gjennom hele livsløpet til de materialene som inngår i produktet. Side 3 informerer om bidrag til effektkategoriene slik de står oppført i Tabell 18.1. EPDen informerer videre om de viktigste utslipp til luft, vann og jord. Siste side gir opplysning om avfallsscenarier, hvilke systemavgrensninger (dvs. hvor mye av livsløpet som er med i analysegrunnlaget) som er gjort, og hvilke vedlikeholdsscenarier som er benyttet.

Miljødeklarasjon ISO 14025

epd-norge.no
Næringslivets Stiftelse for Miljødeklarasjoner

Bo høyrygget hvilestol

HELLAND®

EPD-nr: 060N
Godkjent (dato) i tråd med ISO14025, § 8.1.4

Verifikasjon av data:
Uavhengig verifikasjon av data og annen miljøinformasjon i deklarasjonen er foretatt av (navn på godkjent LCA-verifisør), i tråd med ISO 14025 § 8.1.3 (og evt. med basis i foretakets ISO 14001-sertifisering).
Verifisert av:

Deklarasjonen er utarbeidet av:
Oddrun Aunet Innselset

PCR:
Produktkategoriregler for sitteløsning (NPCR003 Seating, 2008).

Om EPD:
EPDer fra andre programoperatører er ikke nødvendig vis sammenlignbare.

Informasjon om produsent:
Helland Møbler AS
Strandgata 1, 6250 Stordal
Org.nr:943 511 128

Indikatorverdier pr sitteplass
Fra råvareutvinning til ferdig produkt.

Global oppvarming	39,54 kg CO2-Eq.
Energiforbruk:	874,76 MJ
Garantitid:	5 år

Informasjon om produktet:	Bo høyrygget hvilestol er et helsemøbel.
Funksjonell enhet:	1 Sitteløsning vedlikeholdt i 15 år
Antatt levetid:	15 år
Analyseomfang:	Denne EPD omfatter de deler av livsløpet som er angitt i tabell 1 og i figuren over systemgrenser på siste side.
Årstall for studien	2009
Årstall for data:	LCA-data er generert i GaBi 4 i perioden 2005-2009
Antatt markedsområde:	Europa
Kontaktperson:	

Produktspesifikasjon

Tabell 1. Materialforbruk i produktet

Materialer	Masse kg/sitteløsning	Andel %	Andel fra leverandører med sertifisert miljøstyringsystem.	Andel komponenter med miljødeklarasjon.	Systemgrenser (se siste siste for mer informasjon)
Tre	6,95	35,40 %			A F
Stål	4,37	22,26 %			A F
Emballasje	4,05	20,63 %			A F
Stop/skum	3,76	19,15 %			A F
Lim og lakk	0,50	2,55 %			B F
Total	19,63	100,00 %			

Figur 18.10 Forsiden av en EPD

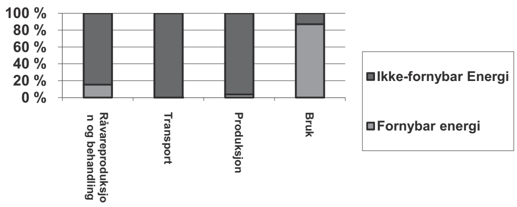
Ressursforbruk

Tabell 2. Materialressurser per livsløpsfase

Kategori	Ressurs	Enhet	Råvareuttak og bearbeiding	Transport	Produksjon	Bruk	Total [kg/sitteløsning]	Kommentar
Fornybare materialer	Vann	kg/sitteløsning	1395,10	0,01	0,95	0,01	1396,08	
	Luft	kg/sitteløsning	12,11	0,01	0,80	0,02	12,94	
	Korn	kg/sitteløsning	0,15	0,00	0,00	0,00	0,15	
Ikke-fornybare materialer	Stein og grus	kg/sitteløsning	37,34	0,00	0,41	0,01	37,77	
	Jernmalm	kg/sitteløsning	7,21	0,00	0,00	0,00	7,21	
	Salt	kg/sitteløsning	4,00	0,00	0,00	0,00	4,00	
	Kalkstein	kg/sitteløsning	2,82	0,00	0,03	0,00	2,85	
	Nikkelmalm	kg/sitteløsning	0,27	0,00	0,00	0,00	0,27	
	Manganmalm	kg/sitteløsning	0,08	0,00	0,00	0,00	0,08	
Resirkulerte ikke-fornybare materialer	Diverse materialer	kg/sitteløsning	29,36	0,00	0,00	0,00	29,36	
Total			1488,44	0,02	2,20	0,04	1490,70	

Landareal og vannressurser.
Landareal er ikke kartlagt. Oversikt over vannforbruk finnes i tabell 2.

Energiressurser
Figur 2. Prosentvis fordeling av energibærere i hver livsløpsfase.



Tabell 3. Energiressurser per livsløpsfase

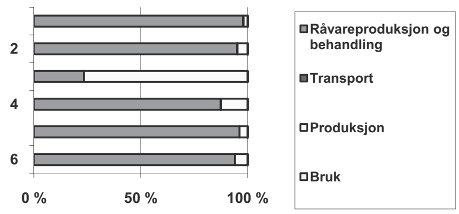
Kategori	Ressurs	Enhet	Råvareuttak og bearbeiding	Transport	Produksjon	Bruk	Total
Fornybar energi	Vannkraft	MJ/sitteløsning	52,88	0,00	23,40	1,47	77,75
	Papir	MJ/sitteløsning	49,27	0,00	0,00	0,00	49,27
	Diverse	MJ/sitteløsning	7,48	0,00	3,75	0,24	11,46
	Biomasse	MJ/sitteløsning	3,33	0,00	0,00	0,00	3,33
	Solenergi	MJ/sitteløsning	1,84	0,00	0,11	0,01	1,96
	Geotermisk energi	MJ/sitteløsning	0,41	0,00	0,00	0,00	0,41
	Vindkraft	MJ/sitteløsning	0,29	0,00	0,03	0,00	0,32
	Tre	MJ/sitteløsning	2,61	0,00	-23,46	0,00	-20,85
Ikke-fornybar Energi	Råolje	MJ/sitteløsning	200,24	0,96	100,71	0,00	301,92
	Naturgass	MJ/sitteløsning	269,27	0,08	6,05	0,01	275,41
	Steinkull	MJ/sitteløsning	130,47	0,00	0,40	0,01	130,88
	Kjernekraft	MJ/sitteløsning	42,41	0,00	0,00	0,00	42,41
	Diverse	MJ/sitteløsning	8,06	0,00	3,75	0,24	12,04
	Brunkull	MJ/sitteløsning	6,86	0,00	0,14	0,00	7,01
	Elektrisk energi	MJ/sitteløsning	4,59	0,00	0,00	0,00	4,59
	Uran	MJ/sitteløsning	2,48	0,00	0,53	0,00	3,01
	Hydrogen	MJ/sitteløsning	1,24	0,00	0,00	0,00	1,24
	Lett fyringsolje	MJ/sitteløsning	0,96	0,00	0,00	0,00	0,96
	Avgasser	MJ/sitteløsning	0,48	0,00	0,01	0,00	0,49
	Uranmalm	MJ/sitteløsning	0,01	0,00	0,00	0,00	0,01
	Plastikk	MJ/sitteløsning	-0,69	0,00	0,00	0,00	-0,69

Utslipp og miljøpåvirkninger

Tabell 4. Miljøpåvirkninger

	Miljøpåvirkning	Enhet	Til fabrikkport	Bruksfase
1	Eutrofiering	kg PO4-ekv	0,0234	9,82E-07
2	Forsuringspotensial	kg SO2-ekv	0,14	6,79E-06
3	Fotokjemisk oksideringspotensial	kg C2H4-ekv	0,0941	5,34E-07
4	Globalt oppvarmingspotensial, 100 år	kg CO2-ekv	39,54	0,009
5	Ozonnedbrytningspotensial	kg R11-ekv	3,71E-07	2,58E-11
6	Tungmetaller, El 95	kg Pb-ekv	3,87E-05	8,4E-09

Figur3: Prosentvis fordeling per livsløpsfase av miljøpåvirkning



Tabell 5. Avfall og største utslipp på vektbasis.

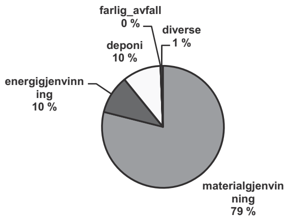
	Avfall og utslipp	Enhet	Råvareuttak og bearbeiding	Transport	Produksjon	Bruk	Total
Avfall, Energigjenvinning	Papir	kg/sitteløsning	2,54	0	0	0	2,54
Avfall, Materialgjenvinning	Metallskrap	kg/sitteløsning	0,622	0	0	0	0,622
	Biogent avfall	kg/sitteløsning	0,1	0	0	0	0,1
Utslipp til luft	Karbondioksid	kg/sitteløsning	28,93	0,067	4,76	0,00956	33,78
	Avgass	kg/sitteløsning	7,52	0,00354	0,644	0,0177	8,19
	Damp	kg/sitteløsning	1,94	0,00205	0,266	0,00345	2,21
	Luft	kg/sitteløsning	1,68	7,6E-06	0,000974	1,12E-05	1,68
	VOC	kg/sitteløsning	0,28	6,61E-05	0,00675	4,31E-06	0,287
	NMVOC	kg/sitteløsning	0,00392	4,4E-05	0,197	3,8E-07	0,201
	Karbonmonoksid	kg/sitteløsning	0,105	0,000128	0,000873	2,9E-06	0,106
	Svoveldioksid	kg/sitteløsning	0,0839	3,02E-05	0,00481	2,11E-06	0,0887
	Nitrogendioksid	kg/sitteløsning	0,0464	2,79E-18	1,32E-11	8,32E-13	0,0464
	Partikler	kg/sitteløsning	0,0269	1,36E-05	0,00391	6,95E-07	0,0308
	Nitrogenoksider	kg/sitteløsning	0,019	0,000546	0,00247	6,47E-06	0,0221
	Hydrogen	kg/sitteløsning	0,00737	1,66E-08	1,77E-06	2,39E-09	0,00738
	Nitrogen	kg/sitteløsning	0,0021	1,11E-06	0,000114	1,11E-07	0,00222
	Klor	kg/sitteløsning	0,00176	8,47E-08	1E-05	7,31E-08	0,00177
	Oksygen	kg/sitteløsning	0,000991	7,08E-06	0,000768	1,62E-06	0,00177
	Amoniakk	kg/sitteløsning	0,00136	4,14E-07	7,02E-06	3,2E-08	0,00137
Utslipp til vann	Klorid	kg/sitteløsning	2,04	0,00111	0,117	9,1E-06	2,15
	Natrium	kg/sitteløsning	0,991	1,4E-06	0,000154	4,79E-07	0,991
	Kalsium	kg/sitteløsning	0,327	4,47E-08	6,16E-06	9,28E-08	0,327
	Faste stoffer	kg/sitteløsning	0,14	4,82E-05	0,00505	5,27E-07	0,145
	Nitrat	kg/sitteløsning	0,0419	2,36E-08	2,59E-06	6,61E-09	0,0419
	Sulfat	kg/sitteløsning	0,0344	1,11E-05	0,00118	1,04E-06	0,0356
	COD	kg/sitteløsning	0,0145	2,6E-06	0,000351	4,98E-06	0,0149
	Nitrogen	kg/sitteløsning	0,00734	9,97E-12	8,48E-09	4,7E-10	0,00734
	Karbonat	kg/sitteløsning	0,00423	1,39E-05	0,00146	4,2E-08	0,00571
	Salter	kg/sitteløsning	0,0036	0	2,66E-14	1,68E-15	0,0036
	Ammonium	kg/sitteløsning	0,00346	5,27E-08	5,68E-06	1,01E-08	0,00347
	Totalt oppløst karbon	kg/sitteløsning	0,00283	2,56E-16	2,68E-10	1,69E-11	0,00283
	BOD	kg/sitteløsning	0,00199	8,36E-08	8,87E-06	5,87E-09	0,002
	Organiske forbindelser	kg/sitteløsning	0,00174	1,07E-07	1,42E-05	1,83E-07	0,00175
	Fosfor	kg/sitteløsning	0,00157	5,33E-09	5,58E-07	3,98E-11	0,00157

Tilleggsinformasjon

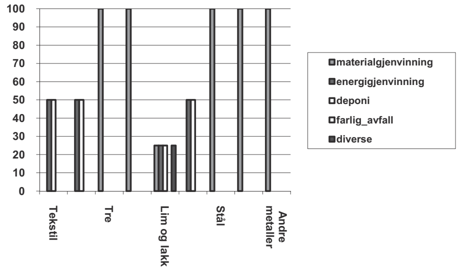
Miljødeklarasjonen er utarbeidet på bakgrunn av produktkategoriregler (PCR) for produktkategorien sitteløsninger (2008). Denne deklarasjonen oppfyller de krav som stilles i de relevante produktkategorireglene.

Møbelets levetid er i henhold til PCR satt til 15 år da dette er den vanlige oppholdstiden hos den første brukeren. Møbelet vil normalt ha lengre teknisk levetid enn dette.

Behandling fra sluttprodukt



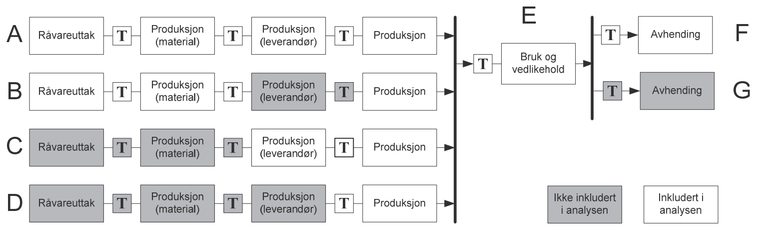
Figur 4: Sannsynlig slutthåndtering for Bo høyrygget hvilestol



Figur 5: Sannsynlig slutthåndtering for ulike materialer.

Det er i denne analysen brukt gjennomsnittlig slutthåndtering for ulike materialtyper basert på informasjon fra Statistisk Sentralbyrå, se figur 5, som viser den prosentvise slutthåndteringen for hver materialtype. Figur 4 viser den prosentvise avhendingen av møbelet.

Metodiske beslutninger



Figur 6: Systemgrenser. Se tabell 1 for spesifikasjon av systemgrenser for denne deklarasjonen.

Kriterier for inkludering av strømmer:

Utgangspunktet for beregningene er 1 % cut-off i forhold til produktets miljøbelastning.

Bruksfasen:

Bruksfasen er representert ved et bruksscenarie i Norge. Inkludert er transport til kunde, støvsuging av tekstiler annethvert år og tekstilutskifting én gang i løpet av vedlikeholdstiden. Vask av metall og plast er ikke inkludert. Disse antagelsene ligger til grunn i LCA-analysen som er gjennomført for møbelet.

Avhendingsfasen:

Avhending er basert på gjennomsnittlig avhending av materialer i Norge i 2008. Møbelets avhending vil sannsynligvis være mindre miljøbelastende enn det som fremkommer i denne deklarasjonen.

Allokeringsregler:

For nytt materiale er råvarer og produksjonsprosesser inkludert. For inngående resirkulert materiale er resirkuleringsprosessen inkludert. Hvor økonomisk allokering ikke har vært mulig å gjøre, er det allokert etter produksjonsvolum. Hvilke prosesser dette gjelder er beskrevet i dokumentasjonene til Møbeldatabasen.

Referanser

Siste side inneholder også referanser til bakgrunnsdataene for EPDen. Her refereres det til analyseverktøyet DATSUPI. Informasjonen som oppgis i en EPD er omfattende, og det er derfor inkludert noen nøkkelindikatorer i rød ramme på EPDens forside. For sittemøbler er globalt oppvarmingspotensial, energiforbruk, andel resirkulert materiale og garantitid valgt som nøkkelindikatorer. Figur 18.11 viser side 2 til 4 av den samme EPDen.

ISO14025 sier at EPDens format skal spesifiseres i PCR. Utseendet kan derfor variere fra land til land, og fra bransje til bransje. Formatet som er vist i figur 18.10 og figur 18.11 følger NIMBUS-formatet, som er utviklet i et nordisk samarbeidsprosjekt (Hanssen et al., 2001). Formatet kan variere noe fra industri til industri. EPDer for byggevarer har for eksempel sitt eget format. Det arbeides videre med å harmonisere EPD-formatet, både mellom bransjer og mellom internasjonale EPD-ordninger. En konstant utfordring er å inkludere nok informasjon for eksperter på ytre miljø, samtidig som det ikke bør være for mye informasjon for ikke-eksperter å ta stilling til.

Annet som kan inkluderes i produktinformasjon

EPDer, som de som er presentert ovenfor og i henhold til ISO 14025, inneholder i hovedsak miljøinformasjon. PCR kan imidlertid gi åpning for å inkludere annen type informasjon, for eksempel arbeidsmiljøforhold i produksjonsfasen eller forhold om potensiell helsemessig påvirkning ved bruk av produktene. Bruk av kjemikalier kan ha en effekt i begge disse tilfellene.

Som nevnt innledningsvis er en av målsettingene for DATSUPI å frembringe informasjon om bærekraftighet som kan brukes i et internasjonalt marked. For påvirking av det ytre miljøet finnes det anerkjente metoder for å beregne et produkts bidrag til miljøeffektkategorier i et livsløpsperspektiv. Tilsvarende enhetlige standarder finnes ikke for arbeidsmiljø eller innemiljø. Innemiljøeffekter ved bruk av produktene må vurderes ut fra emisjonsdata i henhold til gitte standarder. Standarder kan imidlertid variere fra land til land, og variasjonene går både på hva som skal måles (hvilke typer emisjoner som er inkludert i teststandarden), og hvordan det skal måles (hvilke dager testen skal utføres på, for eksempel etter 3, 7 eller 21 dager). For ulike merkeordninger er det også variasjon i fastsettelse av grenseverdier for ulike emisjoner. Det er også variasjoner fra produktgruppe til produktgruppe, avhengig av hvilken påvirkning produktene kan ha på arbeidsmiljø og innemiljø. Mulig eksponering i et arbeidsmiljø kan stamme fra bruk av kjemikalier og løsemidler, støy og støv. Mulige emisjoner fra et møbel i innemiljøet kan være flyktige organiske forbindelser (VOC) og formaldehyd og andre aldehyder, kalt semi-flyktige organiske forbindelser (SVOC). Disse stoffene kan ha en negativ helseeffekt.

Arbeidsmiljø- og innemiljøeffekter

For å kunne inkludere arbeidsmiljø- og innemiljøeffekter i DATSUPI benyttes en tredelt framgangsmåte:

1. Identifisere og klassifisere kjemikalier i produksjonen, som kan ha en negativ helseeffekt. Her ble blant annet OBS!-listen, Stofflisten, Prioritetslisten og REACH-direktivet benyttet. (Statens forurensningstilsyn, 2009.)
2. Identifisere hvilke typer emisjoner fra møbler som kan ha en negativ helseeffekt, og etablere vurderingskriterier for å avgjøre grenseverdier for slike emisjoner. Denne delen bør baseres på en gjennomgang av hvilke typer emisjoner og grenseverdier som er definert i eksisterende merkeordninger for møbler og byggprodukter, blant annet finske «Emission Classification of Building Materials» (The Building Information Foundation RTS, 2009), tyske Blue Angel (The Blue Angel, 2009), amerikanske Greenguard (Greenguard Environmental Institute, 2009) og BIFMA (The Business and Institutional Furniture Manufacturer's Association, 2009).
3. Identifisere hvilke metoder og tekniske kriterier som kan benyttes for måling av emisjoner fra møbler. Her kan blant annet AgBB-metoden (benyttes i Blue Angel-ordningen) og testmetodene som er spesifisert for M1 og BIFMA vurderes.

Målingen av emisjoner gjennomføres i testkammer, i henhold til standardene ISO16000-3 (International Organization for Standardization, 2001b) og ISO16000-6 (International Organization for Standardization, 2004b), ISO 16000-9 (International Organization for Standardization, 2006b) og ISO16000-11 (International Organization for Standardization, 2006c).

DATSUPI – v2 (2009-2010) skal inneha funksjoner som gjør det mulig å fremskaffe sosial informasjon. I første omgang vil det si informasjon som reflekterer produktansvaret i forhold til mulige helseeffekter, som kan oppstå ved produksjon og bruk av produktet.

Spesielt for arbeidsmiljø

Forhold som det skal kunne rapporteres om når det gjelder arbeidsmiljø, er stoffer som er klassifisert i forhold til helseskade, og disse kan vektes ut fra grad av helseeffekt. Kriterier for vekting (1) er gitt etter skalaen som er oppgitt i Tabell 18.2.

Klassifisering **Risikosetninger angitt med nummer** (Forskrift om klassifisering, merking o.a. av farlige kjemikalier)	**Vekting (1) basert på grad av helseeffekt**
Kreftfremkallende, mutagene og reproduksjonsskadelige kjemikalier (CRM-stoffer): R: 45, 46, 49, 40, (68), 60, 61, 62, 63	1000
Meget giftige stoffer, allergifremkallende (luft), fare for varig skade og skade på barn som får morsmelk: R26, 27, 28, 39, 64, 42, 39 kombinert med 26/27 eller 28	100
Giftige stoffer, allergifremkallende (hud), sterkt etsende, mulig fare for varig skade: R 43, 35, 23, 24, 25, 35, 33, 39 kombinert med 23/24 eller 25, 48 kombinert med 23/24 eller 25	10
Etsende helseskadelige (eller irriterende) stoffer R: 34, 20, 21, 22, 34, 41, 36, 37, 38, 48 kombinert med 20/21 eller 22	0,1
Ikke klassifiseringspliktig	0

Endelige effekter i arbeidsmiljøet kan baseres på en tilleggsvekting som er basert på bruk av verneutstyr eller andre forebyggende tiltak. Slike tiltak skal imidlertid alltid dokumenteres. Dette er forhold som kan klassifiseres som sosialt ansvar, og som vil bidra til at eksponeringen på arbeidsplassen reduseres. Dette vil variere om produksjonen foregår i Norge eller i for eksempel Kina, som har lavere arbeidsmiljøstandarder og manglende krav til verneutstyr. Metoden for å hente inn denne typen informasjon kan oppsummeres på følgende måte:

1. Innhente HMS-datablader for alle kjemiske produkter som inngår i produktet og brukes av hovedbedriften.
2. Innhente opplysninger om hvor store mengder av hvert av de merkepliktige stoffene som inngår i produktet.
3. Innhente opplysninger om hvilke mengder halvfabrikata og ferdigproduserte varer som inngår i produktet.
4. Innhente arbeidsmiljørapport fra hovedbedriften.
5. Innhente opplysninger om de delene av produktet som er produsert av andre.
   a) Finnes det HMS-datablader fra produksjonen?
   b) Finnes det arbeidsmiljørapporter fra produksjonen?
6. Innhente opplysninger om halvfabrikata og kjemiske produkter (f. eks. lim og maling) som er brukt i produksjonen.
   a) Finnes det HMS-datablader fra produksjonen?
   b) Finnes det arbeidsmiljøopplysninger fra produksjonen?

Basert på arbeidsmiljøinformasjon som er hentet inn i henhold til punktene 1-6 ovenfor, kan et arbeidsmiljøforhold kvantifiseres ved hjelp av vektingsfaktorer (2) basert på en skala mellom 0,01 og 10 avhengig av implementerte tiltak.

Begrepet «Inherent health factor» betegner grad av helseeffekt og kan beregnes på følgende måte:

*Inherent health factor = masse produkt (kg) * vekting (1) eller vekting (2) hvis beskyttelse i arbeidsmiljøet er dokumentert.*

Basert på innhentet informasjon om eksponering i arbeidsmiljøet og innførte arbeidsmiljøtiltak, kan en endelig «Inherent health factor» for produktet beregnes hos underleverandører og sluttprodusenter. Dette er imidlertid forhold som ofte er vanskelig å kvantifisere eksakt, og er derfor et uttestingsobjekt i DATSUPI.

Spesielt for innemiljø ved bruken av produktet

Det er ulike avdampninger (emisjoner) fra møbler, avhengig av hvilke materialer som inngår i møblene. Avdampningen avtar over tid og avhenger blant annet av hvilke materialer som er brukt og hvordan de er satt sammen (et setetrekk vil for eksempel forsinke avdampning fra seteputen). For å dokumentere forhold som gjelder mulig helseeffekter av materialer som inngår i produktet, er innemiljøindeksene i tabell 18.3 benyttet i DATSUPI.

Stoffene som avdamper, kan bidra til de forskjellige indeksene på forskjellige måter, og ofte bidrar de til flere av indeksene samtidig. Stoffene kan ha en effekt på luftkvaliteten i rommet der møbelet står. Flyktige organiske forbindelser (VOC) og semi-flyktige organiske forbindelser (SVOC) påvirker luftkvaliteten, og disse kan eksempelvis føre til irritasjon i luftveiene og ubehagsproblemer. Disse og andre kjemikalier i møbelet kan også ha andre helseeffekter og gi bidrag til indeksene for kreft, reprotoksisitet, allergi og toksikologisk potensial.

I DATSUPI identifiseres og klassifiseres stoffene, slik det er vist i høyre kolonne i tabell 18.4.

Enkelte materialer kan også avgi ubehaglig lukt, noe som igjen kan føre til ubehag og hodepine. Lukt er ikke inkludert i DATSUPI.

INDEKS	KLASSIFISERING
Luftkvalitet	
Kreftpotensial	Fra kategori 1 (påvist kreftfremkallende hos mennesker) til kategori 3 (bekymring for at stoffet er kreftfremkallende hos mennesker).
Arveegenskap- og reproduksjons-skadelighet	Fra kategori 1 (påvist redusert forplantningsevne, fosterskader eller arvestoffskader hos mennesker) til kategori 3 (bekymring for at stoffet kan føre til skade på forplaningsevne, foster eller arvestoff).
Allergipotensial	Stoffer med risikosetning R42 eller R43 identifiseres, siden de kan fremkalle allergi og overfølsomhet i øyne og luftveier eller ved hudkontakt.
Toksikologisk potensial	

Utfordringer for verktøy som DATSUPI

Metodikk for systematisering av effekt fra eksponering i arbeidsmiljøet og innemiljøet ved bruk av produktet, er ikke helt i tråd med den metodikken som benyttets ved LCA-analyser for ytre miljø, se figur 18.5.

For enhetlig fremstilling av CSR-informasjon om produkter, er det fortsatt en utfordring å få etablert en felles effektevalueringsmetodikk, eller et sett med felles prinsipper for evaluering. Stoffer som benyttes i arbeidsmiljøet og klassifiseres i henhold til tabell 18.2 bør videre kunne kategoriseres i henhold til indeksene som er presentert i tabell 18.4. Det vil da være mulig å benytte samme kategorisering av helseeffekter i produksjons- og bruksfasen. Det bør imidlertid være klart at verdiene i hver effektkategori ikke kan summeres for de ulike livsløpsfasene, ettersom det er forskjellige personer som eksponeres. Et sett med felles indeksering (effektkategorier) vil imidlertid være en god indikasjon på sosiale forhold som er knyttet til produktet.

En utfordring for alle verktøy som skal gi produktinformasjon i et livsløpsperspektiv, er å frembringe kvalitetssikret informasjon fra leverandører og underleverandører. Hva som rapporteres og hvordan det rapporteres, kan variere fra bedrift til bedrift, og metoder for sammenslåing og aggregering av data må utvikles. En annen utfordring er at indikatorsystemet som brukes i verktøyet må gi informasjon som er nyttig over tid, både for industrien og for andre interessenter. En tredje utfordring er å utvikle robuste dataløsninger, med tanke på sikkerhet (beskytte virksomhetsrelatert informasjon) og mulighet for oppdatering (produktinformasjon er ferskvare og må oppdateres jevnlig).

Produktinformasjon og samfunnsansvar – en oppsummering

Utarbeidelse av produktrelatert informasjon er, som nevnt innledningsvis, én måte bedrifter kan arbeide med samfunnsansvar på. Samfunnsansvar i DATSUPI-sammenheng er 1) arbeidsmiljø i produksjonsfasen 2) innemiljø hos bruker av produktet og 3) ytre miljø i verdikjeden.

Dette kapitlet startet med å gi en oversikt over dokumenter og krav som næringslivet må forholde seg til når det gjelder dokumentasjon av samfunnsansvar.

Ved å utarbeide produktinformasjon bidrar en bedrift til å imøtekomme statlige målsettinger om samfunnsansvar. Bedrifter vil være i stand til å følge *regnskapsloven* og *miljøinformasjonsloven* der en EPD dekker de vesentligste aspektene innen ytre miljø for produkter. Når en EPD er tilgjenglig, vil offentlige og private innkjøpere som stiller krav i sine anskaffelser, ha et objektivt og verifisert beslutningsgrunnlag å ta sine avgjørelser på. Fokuset i DATSUPI på arbeidsmiljø og innemiljø møter også den offentlige satsningen på kjemikaliebruk, slik *Sammen for et giftfritt miljø* (St.meld. nr. 10, 2006-2007) setter fokus på.

Fra produsentens ståsted kan denne informasjonen også benyttes internt i forbindelse med produktutvikling. Eksternt kan de benyttes som grunnlag ved innkjøp og hjelpe innkjøperen med å velge det produktet med lavest bidrag til de forskjellige parametrene og effektkategoriene.

Bruk av EPD og annen informasjon fra DATSUPI gjør også innkjøpere i offentlig sektor i stand til å imøtekomme handlingsplanen *Miljø- og samfunnsansvar i offentlige anskaffelser* (Miljøverndepartementet, Fornyings- og administrasjonsdepartementet, Barne- og likestillingsdepartementet, 2007). Tilgang på enkle verktøy er viktig for å gjøre analyser og ha et grunnlag for å ta de rette valgene av materialer og prosesser. Slike verktøy er spesielt viktig for små og mellomstore bedrifter som normalt ikke har ressurser til å gjøre avanserte miljøanalyser.

Tradisjonelt har miljøfokus i industriproduksjon hatt fokus på produksjonsstedet. Eksemplet som er fremstilt i dette kapitlet har også vist at kravet om utvidet produsentansvar er ivaretatt ved at verdikjeden og avhendingsscenarioer er inkludert i dokumentasjonen. Utvidet produsentansvar betyr nemlig at fokus skal rettes mot hele verdikjeden, se figur 18.1. Videre har samfunnsansvar i verdikjeden ofte fokusert på problemer med barnearbeid, korrupsjon og lignende på leverandørsiden. Studier har vist at det har vært vanskelig å kvantifisere denne typen informasjon. Dette kapitlet viser én måte å fremstille kvantifisert informasjon på som dekker viktige CSR-aspekter, som arbeidsmiljø, ytre miljø og potensielle helseeffekter i bruksfasen av et produkt. Dette er demonstrert med verktøyet DATSUPI for møbelindustrien. Når det er enighet om metoder og et enhetlig sett med indekser for effektkategorier er på plass, kan metodikken og informasjonen utvides til å gjelde flere ledd oppstrøms i verdikjeden. Dette vil på sikt kunne gi et verktøy for CSR-dokumentasjon av produkter for hele verdikjeden.

Referanser

Arbeids- og inkluderingsdepartementet (2005). Lov om arbeidsmiljø, arbeidstid, stillingsvern mv. (arbeidsmiljøloven).

Arbeids- og inkluderingsdepartementet og Miljøverndepartementet (2002): Forskrift om klassifisering, merking mv. av farlige kjemikalier.

Brønnøysundregistrene (2009). EMAS-registrerte områder i Norge. http://www.brreg.no/registrene/emas/emasliste.html

Debio (2009). http://www.debio.no.

Der Grüne Punkt (2009). http://www.gruener-punkt.de

European Commission (2004). Buying green! A handbook on environmental public procurement. Office for Official Publications of the European Communities.

European Commission (2009). ELCD database v 1.0.1. http://lca.jrc.ec.europa.eu/lca-infohub/datasetArea.vm.

Fet, A. M. & Skaar, C. (2006). Eco-labeling, Product Category Rules and Certification Procedures Based on ISO 14025 Requirements. *International Journal of Life Cycle Assessment 11*(1), s. 49-54

Fet, A. M., Skaar, C. & Michelsen, O. (2009). Product category rules and environmental product declarations as tools to promote sustainable products: experiences from a case study of furniture production. *Clean Technologies and Environmental Policy* 11(2), s. 201-207.

Finansdepartementet (1998). Lov om årsregnskap m.v. (regnskapsloven).

Forest Stewardship Council (2009). http://www.fsc.org

Global Compact (2009): http://www.globalcompact.org

Global Reporting Initiative (2009). http://www.globalreporting.org

Greenguard Environmental Institute (2009). http://www.greenguard.org

Hanssen, O.J., Stranddorf, H.K., Vold, M., Solèr, C., Hoffmann, L. & Tillman A-M. (2001): Nordic Co-ordinating System for Environmental Product Declarations (Type III). Fredrikstad, Stiftelsen Østfoldforskning (STØ).

International Organization for Standardization (2000). Miljømerker og deklarasjoner: Miljømerking type I: Prinsipper og prosedyrer (NS-EN ISO 14024:2000). Oslo: Standard Norge.

International Organization for Standardization (2001a). Miljømerker og deklarasjoner: Egendeklarerte miljøpåstander (Miljømerking type II) (NS-EN ISO 14021:2001. Oslo: Standard Norge.

International Organization for Standardization (2001b). ISO 16000-3:2001 Indoor Air –Part 3: Determination of formaldehyde and other carbonyl compounds – Active sampling methods.

International Organization for Standardization (2002). Miljømerker og deklarasjoner: generelle prinsipper (NS-EN ISO 14020:2000). Oslo: Standard Norge.

International Organization for Standardization (2004a). Miljøstyringssystemer: spesifikasjon med veiledning (ISO 14001:2004). Oslo: Standard Norge.

International Organization for Standardization (2004b). ISO 16000-6:2004 Indoor Air-Part 6: Determination of volatile organic compounds in indoor and test chamber air by active sampling on Tenax TA sorbent thermal desorption and gas chromatography using MS/FID

International Organization for Standardization (2006a). Miljømerker og deklarasjoner: Miljødeklarasjoner type III: Prinsipper og prosedyrer (NS-EN ISO 14025:2006). Oslo, Standard Norge.
International Organization for Standardization (2006b). ISO 16000-9:2006 Determination of the emission of volatile organic compounds from building products and furnishing – Emission test chamber method.
International Organization for Standardization (2006c). ISO 16000-11:2006 Determination of the emission of volatile organic compounds from building products and furnishing – Sampling, storage of samples and preparation of test specimens.
International Organization for Standardization (2006d). Miljøstyring – Livsløpsvurdering – Prinsipper og rammeverk (NS-EN ISO 14040:2006). Oslo: Standard Norge.
International Organization for Standardization (2006e): Miljøstyring – Livsløpsvurdering – Krav og retningslinjer (NS-EN ISO 14044:2006). Oslo: Standard Norge.
International Organization for Standardization (2007). The ISO Survey 2007. http://www.iso.org/iso/survey2007.pdf
Japan Environmental Management Association for Industry (JEMAI) (2002). Introduction of the EcoLeaf environmental Program guidelines. Japan.
Jolliet O., Müller-Wenk R., Bare J., Brent A., Goedkoop M., Heijungs R., Itsubo N., Peña C., Pennington D., Potting J., Rebitzer G., Steward 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*, s. 394-404.
Korea Eco-Products Institute (2009). Environmental Declaration of Products. http://www.edp.or.kr/eng_index.asp
Miljøverndepartementet (2003a). Lov om rett til miljøinformasjon og deltakelse i offentlige beslutningsprosesser av betydning for miljøet (miljøinformasjonsloven).
Miljøverndepartementet (2003b). Miljøledelse i staten – Prosjekt Grønn stat.
Miljøverndepartementet (2004). Forskrift om begrensning av forurensing (forurensningsloven), kapittel 38. Frivillig deltaking for organisasjoner i en fellesskapsordning for miljøstyring og miljørevisjon (EMAS).
Miljøverndepartementet, Fornyings- og administrasjonsdepartementet, Barne- og likestillingsdepartementet (2007). Miljø- og samfunnsansvar i offentlige anskaffelser – Handlingsplan 2007–2010.
Næringslivets Stiftelse for Miljødeklarasjoner (2009). http://www.epd-norge.no
PE International (2009). http://www.gabi-software.com
Rapport 1998:4. Chalmers, Göteborg.
Row J. & Wieler, C. (2003). Environmental Labelling for Hydrogen in Canada. Drayton Valley: The Pembina Institute.
St.meld. nr. 10 (2008-2009). Næringslivets samfunnsansvar i en global økonomi. Utenriksdepartementet.
St.meld. nr. 14 (2006-2007). Sammen for et giftfritt miljø – forutsetninger for en tryggere fremtid. Miljøverndepartementet.
Statens forurensningstilsyn (2009). Kjemikalier. http://www.sft.no/tema_3316.aspx.
Stiftelsen Miljømerking (2009). http://www.ecolabel.no
Swedish Industrial Research Institutes' Initiative, SIRII (2002). Guidelines to Type III Environmental Declarations. SIRII, Sverige.

The Blue Angel (2009): http://www.blauer-engel.de/en/index.php.
The Building Information Foundation RTS (2009). http://www.rts.fi/emission_classification_of_building_materials.htm
The Business and Institutional Furniture Manufacturer's Association (BIFMA) (2009). http://www.bifma.org
Tillmann, A-M. (1998). LCA-baserade miljövarudeklarationer typ III.

Appendix 6

Integrating Human Health Impact from Indoor Emissions into an LCA: A Case Study Evaluating the Significance of the Use Phase.

DOI: 10.1007/s11367-012-0506-8

Integrating Human Health Impact from Indoor Emissions into an LCA: A Case Study Evaluating the Significance of the Use Phase

Christofer Skaar* and Rikke B Jørgensen
Department of Industrial Economics and Technology Management
Faculty of Social Sciences and Technology Management
Norwegian University of Science and Technology (NTNU)
N-7491 Trondheim
Norway

* Corresponding author contact information:
Phone: +47 73 59 36 93
E-mail: skaar@iot.ntnu.no

First version submitted to International Journal of Life Cycle Assessment in January 2012.

Revised version submitted in May 2012 and accepted in September 2012.

ABSTRACT

1. Purpose

Indoor emissions of toxic substances from products can have a negative effect on human health. These are typically not considered in a Life Cycle Assessment (LCA), potentially underestimating the importance of the use phase. The purpose of this paper is to develop a method that calculates the impact on human health during the use phase, based on a set of measured emission rates.

2. Methods

Emissions from a product are measured in a test chamber and reported as a set of emission rates (µg/h) at specific points in time (hour/day). Constrained non-linear regression (CNLR) analysis is then used to determine parameters for three emission models, and a model is selected based on goodness of fit with the measured emission rates (R2 and expert judgement). The emission model is integrated over a defined time period to estimate the total use phase emissions per functional unit (FU). The total emissions are subsequently integrated in a homogeneously mixed one-box model within the USEtox model. Intake fraction (iF) is calculated based on size of residential home, inhalation rate, exposure time, ventilation rate, mixing factor and number of people exposed.

3. Results and discussion

The method is tested in a case study of chair, with the results showing that the impacts in the use phase are in most cases significantly higher than from production and disposal phases combined. The sensitivity to parameter variations is evaluated. Intake fraction (factor of 761), replacement frequency (factor of 70) and emission model (factor of 24) are found to be the most important model parameters. Limiting early exposure (> 14 % of emissions may occur in the first month and > 50 % in the first year) and replacing furniture less frequently will reduce exposure.

4. Conclusions

The case study shows that the impact on human health from indoor emissions can be of significance, when compared to the impact on human health from total outdoor emissions. Without specific exposure data (e.g. ventilation rates) the uncertainty will be high. The developed method is applicable to all products that emit VOCs, provided that the emission rate can be modelled using an exponential decay model and that the product amount is related to a meaningful functional unit. It is recommended that when performing an LCA of products that emit volatile organic compounds (VOCs), the indoor use phase is included in the life cycle impact assessment (LCIA).

KEYWORDS

indoor emission modelling, USEtox, indoor air quality, human health, life cycle impact assessment, furniture

1. Introduction

Indoor emissions of toxic substances can have a significantly higher impact on human health than outdoor emissions. This is due in part to indoor concentrations being higher than outdoor concentrations (Sexton et al. 2003) and in part to people spending the majority of their time indoors (Brasche and Bischof 2005). This hazard is well known; reducing indoor emissions of toxic substances such as formaldehyde from building materials has been a goal for more than four decades (Salthammer et al. 2010). Although these reduction efforts have been successful, indoor concentrations in residential homes have been reduced to a lesser degree than anticipated (Hun et al. 2010). This is an indication of additional emission sources being present. This is supported by studies showing that furniture can be a significant source of formaldehyde (Blondel and Plaisance 2011).

Public demand for stronger regulation of emissions from building materials and products (e.g. furniture, carpets) is continually growing (Kuehn 2008), and labelling schemes have also addressed this issue (Nordic Ecolabelling 2011a, b; Greenguard 2011). However, in most instances these are based on risk assessments that use emission rates measured within a specific number of days after production, rather than over the life of the product. An example of this is the Nordic Swan requirement for building, decoration and furniture panels that, where formaldehyde emissions must be below 0.065 mg/m^3 (Nordic Ecolabelling 2011b), measured after 28 days with the M1 testing protocol (Saarela and Tirkkonen 2004). The long-term effect of low level exposure is typically not assessed, and the results are not related to impacts other stages in the life cycle. This may lead to problem shifting from environmental to human health aspects or from one life cycle stage to another. Including these impacts in an LCA will influence the final result, and "could even lead to human toxicity becoming a dominant impact category for certain products such as paints, furniture, or carpets" (Hellweg et al. 2009).

The goal of this paper is to develop a method that, based on a set of measured emission rates, can be used to calculate the impacts on human health during a product's use phase. This will be done by first determining the most significant parameters for modelling emissions, exposure and human health impact, respectively. Secondly, the significance of the use phase will be evaluated empirically in a case study of a chair. This work builds on previous research on indoor emission modelling (Guo 2002a, b), Hellweg et al.'s (2009) proposed framework for integrating indoor exposure with life cycle impact assessment (LCIA) and the UNEP/SETAC toxicity model (Rosenbaum et al. 2008).

2. Methods

Including the impact on human health from indoor emissions into the LCIA stage of an LCA requires that an emissions inventory is established, and that for each substance in the inventory a characterisation factor is developed (as shown in Fig. 1). For this purpose a combination of existing models from occupational health, toxicology and life cycle assessment is used. The steps needed to go from emission rates to impact on human health are described below.

<figure 1>

2.1 Emission rates and emission models

Emissions from a product are measured in a test chamber and reported as a set of emission rates (μg/h) at specific points in time (hour/day). This is in contrast to the LCA methodology where the focus is on the total input and output, not on rates (International Organization for Standardization 2006a). The total output is therefore found by integrating a time dependent emission model over a defined time period.

Selecting an emission model that fits is limited by our lack of knowledge of the diffusivity of the product, of the initial amount of VOC in the product and of any characteristics of the room it will end up in (volume, air exchange, loading). Guo et al. (2002a) reviewed 52 indoor emissions source models. The majority of the models are intended for specific applications (e.g. emissions from surface coating), for instant or constant emissions, or are pure data-fitting models. These are considered not applicable for general emissions modelling. Of the 6 remaining models, 3 are not included because they are equivalent to one of the other models and thus redundant. The three chosen models are all decay models based on emission rate being controlled by internal diffusion, and not limited by vapour pressure. This assumption is considered reasonable as we are interested in total mass emitted, and not in concentrations (Tichenor and Guo 1991). The models are presented below. Equation 1 is a first-order decay model (Guo 2002a), Equation 2 is a *n*th-order decay model (Tichenor et al. 1992) and Equation 3 is a dual first-order decay model (Guo 2002a).

$$E = E_0 \cdot e^{-kt} \quad (1)$$

$$E = \frac{E_0}{\left[(1+(n-1)\cdot k \cdot t \cdot E_0^{n-1}\right]^{1/(n-1)}} \quad (2)$$

$$E = E_1 e^{-k_1 t} + E_2 e^{-k_2 t} \quad (3)$$

where E is emission rate and E_0, E_1 and E_2 are initial emission rates, k, k_1 and k_2 are decay rates and t is time. Unknown parameters are found using constrained non-linear regression analysis (CNLR) (SPSS 2010). This requires that minimum 3-5 data points are measured, as there are 2-4 unknown parameters. A specific indoor emission model can then be selected, based on an evaluation of the goodness of fit. Note that the indoor emission models originally refer to emission factor (e.g. µg/m2/time) and not emission rate per product (µg/time), but the emission factor and emission rate are proportional.

2.2 Indoor exposure model

Following the recommendations of Hellweg et al. (2009) a homogeneously mixed one-box model is used to model indoor exposure from a product. The model is connected to the surroundings through ventilation. The model is further simplified by disregarding any concentrations of substances in the ingoing ventilation air, limiting the focus to the additional impact of the product.

Inhalation is assumed to be the most significant exposure pathway, thus excluding dermal contact and ingestion from the assessment (Meijer et al. 2005). To estimate the impact on human health, we must know how much of the total emitted mass of pollutants is inhaled by human beings. This ratio is defined as the intake fraction (*iF*) (Bennett et al. 2002). The intake fraction (dimensionless) is calculated using Equation 4, based on Hellweg et al. (2009):

$$iF = \frac{IR}{V \cdot k_m \cdot k_{ex}} \cdot N = \frac{IR \cdot h}{V \cdot k_m \cdot 24 \cdot k_{ex}} \quad (4)$$

where IR is inhalation rate (m^3/hour), h is exposure time (hour/day), V is room volume (m^3), k_m is the mixing factor (how well the air is mixed in the room) (dimensionless), 24 is hours per day (hour/day) k_{ex} is the air exchange rate per hour (1/day) and N is the number of people exposed. Assuming one person per product eliminates N from the equation. The *iF* is used to calculate the inhaled mass, using Equation 5:

$$m_{inh} = m_{tot} \cdot iF \quad (5)$$

where m_{inh} is the inhaled fraction of the total output, m_{tot}. The total output is, as previously mentioned, calculated by integrating a time dependent emission model over a defined time period. When performing an LCA, the calculation of m_{tot} should be related to the functional unit (FU) and its reference flows (e.g., are we interested in the total emissions from 1 product over 10 years or the total emissions from 2 products over 5 years each?). In this case m_{tot} becomes mass per FU.

Adsorption and desorption of vapour phase organic compounds influence the concentration variations in real rooms (Singer et al 2007). In this case the emission of VOC and aldehydes from the product will be able to adsorp on other surfaces in the real room, with subsequent desorption to the indoor air, when the room concentration decrease. This is well-proved (Tichenor et al. 1991, Colombo et al 1993, Jørgensen et al. 1999, Jørgensen and Bjørseth 1999). If the product is complex, a combined sink-diffusion model could be even better model than a simple Langmuir Isotherm model (Jørgensen et al. 2000). Another aspect of sorption is that the product itself can be able to adsorp vapour phase organic compounds from other sources in the real room due to its own surface, with corresponding desorption when the room concentration decrease. This is also relevant for complex products, for example products with a large surface.

The influence of sorption on the indoor concentration depends on the sorption capacity of the chemical compounds involved and the material surfaces in the room. No standard method or standard values exists for inclusion of sorption parameters to the emission model. In general more advanced models often fit the data better than simple models, but without knowledge of sorption data, it gives no sense to include sorption into the model used.

2.3 Outdoor exposure model

For outdoor exposure the USEtox model with a nested indoor compartment is used (Hellweg et al. 2009). USEtox^{TM} is a multimedia and multi-compartment environmental fate, exposure and effect model developed by UNEP/SETAC, based on scientific consensus (Rosenbaum et al. 2008). The indoor compartment is, as previously mentioned, linked with the outdoor model through air exchange. The mass of pollutants entering the environment is calculated as the total emitted mass minus that which is inhaled, as shown in Equation 6.

$$m_{ua} = m_{tot} - m_{inh} = m_{tot} \cdot (1 - iF) \quad (6)$$

where m_{ua} is emissions to urban air per FU, with urban air having been selected as the receiving compartment in order to simplify the model, a choice that is assumed to have a negligible effect on the total impact.

2.4 Use phase impact assessment

For every emission the potential indoor and outdoor impact is calculated using Equation 7 and Equation 8:

$$Impact_{h,indoor} = m_{tot} \cdot iF \cdot EF_{inh} = m_{tot} \cdot CF_{indoor} \quad (7)$$

$$Impact_{h,outdoor} = m_{ua} \cdot CF_{ua} \quad (8)$$

where $Impact_{h,indoor}$ and $Impact_{h,outdoor}$ are the impacts on human health [cases per FU], *EF* is the human health effect factor for inhalation of the specific substance [cases per kg intake] (cancer and non-cancer, see the USEtox model for more information (USEtox 2011)) and the *CF*s are the indoor and outdoor characterisation factors of the substances [cases per kg emitted] (also termed Comparative Toxic Units, [CTU]) (Rosenbaum et al. 2008).

The characterisation factor (*CF*) takes into account the potential fate, exposure and effect of the emissions. For indoor emissions, the characterisation factor is defined as intake fraction (*iF*) multiplied with effect factor (*EF*) (Hellweg et al. 2009). The intake fraction is the same for all emissions, but the effect factor is determined individually for every emitted substance based on the ED50 [kg/lifetime] (Rosenbaum et al. 2008). For outdoor emissions the characterisation factors are taken directly from the USEtox model.

3 Application of the method in a furniture case study

In order to evaluate the significance of impacts from emissions in the use phase, a case study of a chair was performed. The chair can be described as a recliner, and is product in ordinary production. The base is made from steel and laminated European beech. The seat is made of upholstery leather, with the inside consisting mainly of polyurethane foam. The total weight of the chair (excluding packaging) is slightly more than 20 kg. First, the emissions from the chair were measured in a test chamber over a period of 28 days using standardised test methods (International Organization for Standardization 2006b, c, 2004, 2001), as described below. Based on these results the impacts on human health were calculated for 1, 3, 5, 15, 30 and 70 years using the methodology presented above (equations 1-8), with 8 hours of indoor exposure time in residential homes per day. 8 hours is based on the assumption that a person is exposed to the emissions from the chair half of the approximately 16 hours spent indoor at home (Brasche and Bischof 2005). Secondly, an LCA was performed according to the Product Category Rules (PCR) for chairs (EPD Norway 2008) in the Norwegian EPD system (Fet et al. 2009), estimating the potential environmental impact of the chair. The functional unit (FU) of the LCA was the provision of seating for one person over 15 years. The occupational exposure in the production and disposal phases was not included in this study, as this was outside the scope of the case study.

3.1 Measuring emission rates

The chair was submitted directly from the manufacturer to the laboratory. The chair was taken directly from the production line, wrapped twice with aluminium foil and then with non-odorous PE or PP foil and send to the lab, shipped via overnight express. The emission rates from the chair were then measured in a test chamber with seven data points (see Table S1 in Supplementary Material for measured values). Chamber tests with the chair were performed according to standardised methods (ISO 2006a, b) in a 3.2 m^2 test chamber (23 °C, 50 % relative humidity and air exchange rate of 0.5 per hour). Samples were taken after 6, 24, 48, 72, 96, 168 and 672 hours, with the chair never leaving the chamber. VOC analyses were performed according to ISO 16000-6 (ISO 2004), and volatile aldehydes C1-C6 according to ISO 16000-3 (ISO 2001). All tests and chemical analyses were performed by Eurofins AS, Galten, Denmark (Eurofins 2012).

3.2 Calculating emission model parameters

Thereafter a CNLR analysis was used to identify parameters for the three selected emission models. For the second model (Equation 2), three variants were included, using *n*-values known to have a good fit with formaldehyde emissions from wood finishing (Tichenor and Guo 1991) (n = 2; n = 2.5; n = 3). Goodness of fit of the emission models to the measured results were evaluated using R^2 (see Table S2 in Supplementary Material) and face validity. The model that fits the measured results best (had the highest sum of R^2) was Equation 2 with n = 2. This was chosen as the base model. This choice is further supported by the knowledge that first-order models “almost always underestimate the long-term emissions” (Guo 2002a) and that *n*th-order models with n higher than 2 “may overestimate the total emissions” (Guo 2002a). The first-order and *n*th-order (with n = 3) models were included in the calculations in order to provide an estimate of the upper and lower bounds of the emissions.

4 Results

3.2 Indoor exposure

The indoor exposure is dependent on the intake fraction, which is here determined by the parameters inhalation rate (0.44-1.04 m^3/hour), volume (150-447 m^3), air exchange (0.5-0.9 per hour) and mixing factor (0.1-1). The ranges are empirical values for residential homes, as presented in Hellweg et al. (2009). The variation in exposure time is 4-24 hours per day. These parameters provide an estimate of the best and worst case scenarios, which may be useful for a sensitivity analysis. Based on these values the intake fraction was calculated using Equation 4, with a range from 0.00018 to 0.1387.

Furthermore, a Nordic household scenario was defined, with values selected within common ranges. The parameters were 0.675 m^3/hour inhalation rate (adult male) (Allan and Richardson 1998), 200 m^3 room volume (Øie 1998), air exchange of 0.5 (Øie 1998) and mixing factor of 0.5 (National Research Council 1991). With 8 hours per day exposure time, the intake fraction for this scenario is 0.0045.

3.3 Outdoor exposure

The amount of emissions entering the environment is calculated using Equation 6, and is dependent on the intake fraction for indoor exposure. Using the intake fraction range calculated above, the fraction of emissions entering the environment ranges from 0.8613 to 0.9998. Outdoor exposure does not require estimation of exposure time, as the USEtox multimedia fate model accounts for this. Subtracting the indoor exposure time of one person is negligible, as the outdoor population in the model is that of a continent.

4.1 Use phase impact on human health

The indoor and outdoor impact on human health from emissions in the use phase is calculated using equations 7 and 8, with variations in intake fraction (low, Nordic average and high), product lifetime (1, 3, 5, 15, 30 and 70 years) and emission model (first-order, n = 2 and n = 3). The outdoor emissions are the residual emissions when the indoor exposure has been subtracted from the total, and are modelled as emissions to urban air. Urban air has been selected instead of rural, to be on the conservative side and to provide model simplicity. Fig. 2 shows impacts in a 15 and 70 year timeframe, with a product lifetime of 15 years. Fig. 3 shows impacts over 70 years for 3 different emission models (Nordic iF). The single most significant indoor emission was found to be formaldehyde, which accounted for more than 96 % of the total impact for emission model n = 2. Distinguishing between cancer and non-cancer effects revealed that cancer effects accounted for 95-99 % of the total impact for all combinations of emission model and intake fraction ($EF_{canc.}$ and $EF_{non\text{-}canc.}$ values for all substances can be found in Table S3 in the Supplementary Material).

<figure 2>
<figure 3>

The results show that the largest variations in indoor impact over a 70 year period are due to variations in intake fraction (factor of 761), replacement frequency (factor of 70) and emission model (factor of 24). For 15 years the factors for replacement frequency and emission model are lower (factor of 15 and 11, respectively). The full results can be found in Table S4 and Table S5 in the Supplemental Information.

Variations in outdoor impact follow the same pattern as indoor impact, with the exception of intake fraction which has the opposite trend to indoor impact, and varies by a factor of 1.16. Indoor exposure is in all cases higher than outdoor exposure, with the order of magnitude varying from one to three and a half depending on intake fraction.

4.2 Life cycle assessment

A life cycle assessment of the chair (excluding the use phase) was performed using GaBi (PE International 2011) and the DATSUPI database (Fet et al. 2009), a database that has been developed specifically for the Norwegian furniture industry. Primary data were used for the furniture manufacturing processes and the most significant sub-supplier processes. Generic data were used for the background processes (raw material production, energy production). For the disposal phase generic data were used, with average Norwegian recycling and waste treatment practices for materials in the chair, as defined in DATSUPI. A high level of material and energy recovery is assumed in the disposal phase, with the environmental impacts of the recovery processes allocated to the recipient systems (as specified in the PCR). The results for 11 impact categories can be found in Table S6 in the Supplementary Material. No normalisation or weighting methods have been applied to the potential impacts shown in this table.

The impacts on human health from the use phase were subsequently compared to the impacts from production and disposal phases. The results show that the combined indoor and outdoor impact in the use phase (Table S4 in the Supplemental Information) is approximately from a factor of four to four and a half orders of magnitude higher than the outdoor impact in the production and disposal phases (Table S6 in the Supplementary Material), taking into account that for each replacement in the use phase a new chair must also be manufactured. The higher the intake fraction, the more important indoor exposure becomes. The choice of emission model also plays a role here. For Nordic intake fraction the range is approximately two to four orders of magnitude between the use phase and the combined production and disposal phases, depending on emission model and replacement frequency.

5 Discussion

The discussion is structured into two parts. The first part relates to the results from the case study, including emission models, intake fraction, effect factors, replacement frequency and significance of impacts. The second part relates to relevance for stakeholders, the generic applicability of the developed method as well as areas for further research.

5.1 Case study

Uncertainty is a central element in the case study results, as the level of uncertainty of the individual elements in the model is high. When discussing uncertainty, it is important to keep in mind the uncertainty of the USEtox *CF*s, which is 100-1000 (i.e. two to three orders of magnitude) (Rosenbaum et al. 2008). It should be noted that any single parameter variation is lower than the uncertainty of the USEtox model (factor of up to 761 compared to a factor up to 1000). The uncertainty distribution and variance of the individual parameters are not known, making it difficult to construct confidence intervals.

5.1.1 Emission models

Choice of emission model influenced the case study results by a factor of 24, mainly due to differences in long term low-level emission estimates. The three model variants included (first order, n = 2 and n = 3) provided values for best, worst and average scenarios. The third emission model (Equation 3) was not included in the case study because it had a low overall R^2-value, and because this emission model requires determining four unknown variables using CNLR analysis, with only seven data points available. Measurement uncertainty (reported by Eurofins AS to be ± 20 %) may also further influence the CNLR analysis. An example of this is the apparent increase in emission rate for some substances (e.g. acetone and n-Undecane at 72 and 96 hours in Table S1 in the Supplementary Material), where measurement uncertainty is the most likely explanation. As emission rates can vary from substance to substance depending on the chemical properties of the individual substances (He et al. 2005), it is possible that the parameters of the emission model and of the CNLR can be refined for individual substances to provide more reliable results.

<figure 4>
<figure 5>

Fig. 4 and Fig. 5 show calculated emission rates for the three selected emission model variants over a period of 1 month and 1 year respectively, as well as measured emissions for the first month. The figure suggests that an *n*th-order model may exist that fits best with the measured emission rates, but determining which *n*-value most accurately represents the real emission rates over time is not possible without measuring emission rates over a longer time period (months or even years). Except for the first-order emission model, all emission models evaluated here postulate that there will continuous emissions throughout the 70 year time period. The validity of assuming that there are constant emissions is unknown, as there are no experimental results to prove or disprove the assumption. Brown (1999) has shown that a dual first-order emission model can describe both short-term and long-term emission rates of formaldehyde from wood panels, but such a model was, as mentioned, excluded from the case study because of lack of data points to perform a CNLR analysis.

All emissions in the case study are assumed to be controlled by internal diffusion and vapour pressure, which were measured (although not separately). This may not be the case in real life, where factors such as sorption, desorption, humidity and temperature can influence the emission rates (Hun et al. 2010). These factors make it difficult to predict the behaviour of long-term emissions. Desorption processes in real life situations can span over years, and are influenced by both the sink materials present in a room as well as the physical and chemical properties of the individual substances themselves (Chang et al. 1998).

5.1.2 Intake fraction

The variation in results for both 15 and 70 years showed that intake fraction was the parameter with highest variation, with a factor of 761 between best case and worst case. This is also the most difficult parameter to predict and generalise, as site specific variations will be large. The intake fraction is here dependent on size of residential home, inhalation rate, exposure time, ventilation rate and mixing factor, parameters that will vary with the age and gender of a person, the size, age and construction technique of the dwelling and from country to country. Examples of this are exposure time and inhalation rate. Inhalation rate has in a Canadian study has been shown to vary from 17.54±4.06 for adult males to 12.84±2.55 for senior females (mean value ± standard deviation) (Allan and Richardson 1998). Wenger et al. (2012) have proposed an intake fraction of 0.01 for volatile organic compounds. Considering the variation in the case study, this is considered to be quite close to the Nordic average intake fraction of 0.0045 defined here.

5.1.3 Effect factors

Only USEtox *EF*s have been used in the case study, leading to 9 of the 35 emissions being assigned zero values because no data were available. 3 of these 9 measured emissions are aggregated totals, and have thus already been accounted for. 1 is a total of unspecified emissions, but as these are unknown it is not possible to assign a meaningful *EF* to them. For the last 5 types of emissions (n-Undecane, 2-Ethylhexyl acetate, n-Dodecane, n-Tridecane and n-Tetradecane) there were no USEtox *CF* available. In order to evaluate the potential significance of these, the emissions were compared to the lowest concentration of interest (LCI) specified in three indoor air quality evaluation schemes (see Table S3 in Supplementary

Material for details). An LCI value is a threshold value used when evaluating or certifying building products intended to safeguard against health risk (AgBB 2010). The three schemes were the European Collaborative Action on Urban Air, Indoor Environment and Human Exposure (ECA 1997), the German Committee for Health-related Evaluation of Building Products (AgBB 2010) and the Afsset guidelines of the former French Agency for Environmental and Occupational Health Safety (Afsset 2009). This evaluation showed that USEtox covered all significant emissions in the data set.

To further evaluate the potential significance of unspecified *EFs*, an additional *EF* set was created. Here all unspecified *EF* values (marked as "not found" or "n/a" in Table S3 in Supplementary Material) were assigned the formaldehyde value in the EF_{canc} column, indented to represent a scenario where substances with unspecified *EF* were as harmful to human health as formaldehyde. Aggregated emissions such as TVOC were not included in this evaluation. For emissions over 15 years and using emission model $n = 2$, this gave a factor of 3 higher impact. This is significantly lower than the uncertainty of the USEtox model itself, and can be interpreted as an indication that the most significant emissions are included in the original set of effect factors.

A limitation of the *EF*s used in the case study is that they only consider inhalation. Dermal contact and ingestion is thus not included, which may lead to underestimation in particular of non-cancer effects (e.g. allergies, asthma and eczema). Other aspects that the *EF*s do not include are potential positive or negative interaction effects of being exposed to a cocktail of substances (Sexton et al. 2005), which can include sensitisation effects (Choi et al. 2010).

5.1.4 Replacement frequency

It has been shown that emissions of formaldehyde are persistent even in a long-term perspective in residential homes, at a level which cannot be explained by emissions from building materials alone (Hun et al. 2010; Blondel and Plaisance 2011). The case study results indicate that rapid replacement of furniture can contribute to significantly higher levels of emitted substances, with a worst case difference of a factor 70 over 70 years (first-order emission model). In the expected lifetime of the chair (15 years according to the PCR), more than 50 % of the emissions will have occurred in the first year using emission model $n = 2$. With this emission model, the difference is a factor of 24. Fig. 6 shows the cumulated impact over a 30 year period, with 5 different replacement frequencies.

<figure 6>

The significance of replacement frequency in these findings relies on the assumption that the chair is placed in a residence from day one. If the first month of emissions occur outside of the residence, the total impact will be reduced by 14 % in a 15 year time period and 16 % in a 30 year time period (emission model $n = 2$). However, with modern production techniques a chair will often be sealed in plastic at the factory and delivered directly to the consumer.

5.1.5 Significance of impacts

The impacts on human health from indoor exposure in the use phase are in the case study higher than from outdoor exposure. The variation is almost entirely dependent on the intake fraction (>99 %). For best case and Nordic intake fractions in the use phase, the indoor exposures are respectively a factor of 7 and 186 higher than for outdoor exposure. It should be noted that these are not significant differences compared to the underlying uncertainty of the USEtox model. Considering how the intake fraction is defined here, a high intake fraction is likely to be due to a small room with low ventilation rate. The results show that in this case a single piece of furniture may have a high impact on the indoor air quality.

It is apparent that outdoor exposure in the production and disposal phases is significantly higher (up to four orders of magnitude) than indoor exposure in the use phase in most cases, except for combinations of low intake fraction with best case emission model (factor of four higher). For Nordic intake fraction, the results are two to three orders of magnitude higher. However, this result may be skewed towards the use phase for two reasons. The first is the possibility that not all hazardous emissions to outdoor is included in the production and disposal (inventory deficiency), and the second is that indoor exposure in the production and disposal phases are outside the scope of the model the case study. The significance of the latter is difficult to estimate, as the population is smaller than in the use phase and the majority will be healthy adults.

In order to assess the potential significance of the case study impacts in general, it can be useful to relate the findings to known emission or effect levels. The WHO recommendation for formaldehyde exposure is a limit of a concentration of 0.1 mg/m3, and takes into account both cancer and non-cancer effects (WHO 2010). Using low, Nordic average and high inhalation frequencies over 70 years (4, 12 and 24 hours per day) and multiplying with the USEtox *EF* for formaldehyde, the impact value is between 0.005 and 0.068 for a person inhaling air with maximum recommended limit over 70 years. The WHO values range from being almost identical to the case study results (indoor and outdoor in the use phase) to six orders of magnitude higher. With Nordic average intake fraction the WHO values are one to four orders of magnitudes higher (whereas the uncertainty within the USEtox model is two to three orders of magnitude). Although the WHO limit values are risk based and thus not directly comparable to the results of the case study, the results are interpreted as an indication that there are indoor exposure scenarios where a single piece of furniture can be of significance.

5.2 Applicability of the developed method

The results of the case study show that manufacturers that intend to investigate the impact on human health from toxic substances in the value chain, should include consumers. Neglecting to do so means that potentially significant health impacts are overlooked, which can lead to problem shifting from the production to the use phase. Any investigation should include long-term as well as short-term effects. The results here support previous recommendations to include human health impacts from indoor emissions into LCA (Hellweg et al. 2009; Wenger et al. 2012).

5.2.1 Relevance for stakeholders

Two stakeholder groups can be identified that are directly affected by the emissions from products (in addition to the general population that is affected through increased background levels of exposure). The first group is consumers and the second is workers in the production and disposal phases.

Methods for integrating occupational health aspects in an LCA have been developed (Kim and Hur 2009; Andrews et al. 2009), but usually without including the consumer in the use phase. For consumers, the case study results show that only with high replacement frequency and poor indoor air quality is impact from indoor exposure from the chair significant. However, the impact may be higher or lower for other product groups (e.g. other types of furniture, carpets or building materials) or when looking at multiple products in a room. Knowing that background levels of formaldehyde concentrations in residential homes tend to stabilise at a relatively high level that is not alleviated by increased ventilation, removing sources is a recommended approach (Hun et al. 2010). Other approaches to reducing indoor exposure from products where the emissions have an exponential decay rate, are increasing ventilation rates in the first months after a purchase, 'airing out' the product before using it (e.g. in a storage room for a period of a month) or acquiring second hand products instead of buying new.

Stakeholders in the production and disposal phase can be distinguished into two groups, where a person may belong to one or both: exposed workers and people at a position to influence emission rates and exposure (e.g. designers, purchasers, occupational hygienists). Emissions from the product itself in the disposal phase are arguably less relevant, in part because of the low level of long-term emissions and in part because of potential exposure to other emissions arising from disposal processes are more significant (e.g. hexavalent chromium arising from leather incineration (Chen et al. 1998)).

5.2.2 Considerations, recommendations and limitations

The method presented through equations 1-8 proposes to calculate the impact on human health from emissions in the use phase, based on a set of measured emission rates. The case study has shown that the model can be applied on a chair, and that the use phase can be significant when compared to outdoor exposure in the production and disposal phases. The method is not specific to furniture, it is intended to be generic and applicable to any type of product where the emission rate can be modelled using an exponential decay model (i.e. equations 1-3). The model is based on the assumption that there is an *n*th order decay model that can describe the emission rate over time, where the optimal *n*-value can vary from one product type to another. For products that are similar to a chair, the method can be applied in a similar manner as in the case study. This applies to products that have long product lifetime and with only one person exposed per product. For other types of products, the following should be considered:

- If the product lifetime is short, it is likely that a first-order emission model (Equation 1) can perform as well as an *n*th order emission model (with $n > 1$) (Equation 2), thus simplifying the emission model.
- If multiple persons are exposed, this must be accounted for when calculating the intake fraction (Equation 4).

In all cases the amount of product(s) (e.g. in units, kg or m^2) should be related to a meaningful functional unit. Furthermore, the results of the case study show that intake fraction and replacement frequency are the most important model parameters. These are also the two most difficult to generalise, as they are entirely dependent on the characteristics of the user and the user's residence. Recognising the level of uncertainty associated with these two parameters, it is recommended that when a sensitivity analysis is performed, the variation in these parameters is always included (for example by using best and worst case estimates).

When applying the method developed here, there are three limitations that the user should be aware of. The first is that only the emissions from the studied product(s) are included, underlining the importance of defining a functional unit that is useful for the intended audience of the LCA. The second is defining the intake fraction. This is especially relevant if the purpose of the LCA is to evaluate the relative importance of life cycle stages (i.e. hot spot analysis), but of less importance when performing comparative studies between product systems. The third is that the one-box model used to model indoor exposure does not take into consideration sink effects in the room where the product is located, thus potentially underestimating the long-term emission rates (Chang et al. 1998). Furthermore, performing a CNLR analysis to find parameters for the emission model requires that there are enough data points. This means that it is not possible to find emission model parameters based on a single emission rate only measured at 28 days, which is required for some types of certification (Nordic Ecolabelling 2011a, b). It is therefore recommended to perform additional measurements during the 28 day interval the product is in the test chamber.

5.2.3 Further research

A number of challenges remain to make the suggested method accessible as a general method that can be used broadly. The first challenge is, as already mentioned, the lack of knowledge on long-term emissions. The measurements performed here ran for less than a month, whereas the lifetime of many products span over decades. The second challenge is also related to emission rates. Laboratory measurements are accurate, but also costly, time consuming and usually do not include long term emission rates. Developing a calculation methodology that can accurately predict short-term and long-term emissions based on product design and material content will make it feasible to include these aspects already in the design phase, for example integrated in CAD software. Such models can also have societal relevance, considering the scale of emissions from products in a national or regional perspective (Rydberg et al. 2012). The third challenge is the relationship between the calculated intake fraction and real life situations, where factors such as mixing, sorption, desorption and multiple emission sources and sinks are present. In general, the effect of adsorption and desorption on material surfaces influence the indoor air during the entire time the product/furniture is in a building (Berglund et al. 1989). Improvements in these areas can reduce the level of uncertainty in the results and improve the precision.

6 Conclusion

This paper has presented a methodology, based on experimentally measured emission rates, which can be used to estimate a product's impact on human health in the use phase when performing an LCA. Three emission models (first order, *n*th order and dual first order) have been evaluated, identifying an *n*th-order model as best suited when there are few data points and long-term emissions are of concern. The results of a case study of a chair have shown that the impact on human health from indoor emissions can be significant, when compared with the impact from outdoor emissions in the other life cycle phases. These impacts are therefore recommended to be considered when performing an LCA of products that emit volatile organic compounds (VOCs). The method is applicable to all products that emit VOCs, provided that the emission rate can be modelled using an exponential decay model and that the product amount is related to a meaningful functional unit. It is recognised that without specific exposure data (e.g. ventilation rates, sorption) the uncertainty will be high. In this case the developed method can be used to indicate if the use phase is a hot spot that should be further investigated. Additional research on long-term emissions in real life situations is needed to reduce the level of uncertainty.

The case study has shown that under certain circumstances the impact from exposure in the use phase may alone be high enough to raise concern. Recommended actions to reduce use phase exposure are limiting early exposure (more than 14 % of emissions may occur in the first month and more than 50 % in the first year) and replacing furniture less frequently. The results favour re-use of furniture, as this will eliminate early exposure for the next users.

Acknowledgements
The PhD position of Christofer Skaar is part of a research programme sponsored by the Norwegian Research Council. Project name: C(S)R in global value chains, a conceptual and operational approach. Project number: 171658.

Supplementary Material

The Supplementary Material contains details on the measured emission rates (Table S1), the evaluation of goodness of fit of the emissions models using R^2 (Table S2), a comparison of the USEtox effect factors to LCI values from ECA (1997), AgBB (2010) and Afsset (2009) (Table S3), impacts in the use phase over a 70 year time span (Table S4), impacts in the use phase over a 15 year time span (Table S5) and LCA results for the production and disposal phases (Table S6).

Literature Cited

Afsset (2009) Saisine Afsset n°2004/11. Maisons-Alfort

AgBB (2010) Evaluation procedure for VOC emissions from building products.

Allan M, Richardson GM (1998) Probability density functions describing 24-hour inhalation rates for use in human health risk assessments. Hum Ecol Risk Assess 4 (2):379-408. doi: 10.1080/10807039891284389

Andrews E, Lesage P, Benoît C, Parent J, Norris G, Revéret J-P (2009) Life Cycle Attribute Assessment - Case Study of Quebec Greenhouse Tomatoes. J Ind Ecol 13 (4):565-578. doi:10.1111/j.1530-9290.2009.00142.x

Bennett DH, McKone TE, Evans JS, Nazaroff WW, Margni MD, Jolliet O, Smith KR (2002) Defining intake fraction. Environ Sci Technol 36 (9):206a-211a. doi:10.1021/es0222770

Berglund B, Johansson I. Lindvall T. (1989) Volatile organic compounds from used building materials in a simulated chamber study. Environt Int 15: 383-387. doi:10.1016/0160-4120(89)90052-4

Blondel A, Plaisance H (2011) Screening of formaldehyde indoor sources and quantification of their emission using a passive sampler. Build Environ 46 (6):1284-1291. doi:10.1016/j.buildenv.2010.12.011

Brasche S, Bischof W (2005) Daily time spent indoors in German homes - Baseline data for the assessment of indoor exposure of German occupants. Int J Hyg Envir Heal 208 (4):247-253. doi:10.1016/j.ijheh.2005.03.003

Brown SK (1999) Chamber Assessment of Formaldehyde and VOC Emissions from Wood-Based Panels. Indoor Air 9(3):209-215. doi: 10.1111/j.1600-0668.1999.t01-1-00008.x

Chang JCS, Sparks LE, Guo Z, Fortmann R (1998) Evaluation of Sink Effects on VOCs from a Latex Paint. J Air Waste Manage Assoc 48(10): 953-958. doi: 10.1080/10473289.1998.10463743

Chen J-C, Wey M-Y, Chiang B-C, Hsieh S-M (1998) The simulation of hexavalent chromium formation under various incineration conditions. Chemosphere 36(7): 1553-1564. doi:10.1016/S0045-6535(97)10053-4

Choi H, Schmidbauer N, Sundell J, Hasselgren M, Spenger J, Bornehag C-G (2010) Common Houshold Chemicals and the Allergy Risks in Pre-School Children. PLoS ONE 5(10):e13423. doi:10.1371/journal.pone.0013423

Colombo A, De Bortoli M, Knöppel H, Pecchio E, Visser H (1993) Adsorption on selected volatile organic compounds on a carpet, a wall coating , and a gypsum board in a test chamber. Indoor Air 3: 276-282. doi: 10.1111/j.1600-0668.1993.00009.x

ECA (1997) Evaluation of VOC Emissions from Building Products. European Comission, Brussels, Belgium

EPD Norway (2008) Product Category Rules for preparing an Environmental Product Declaration (EPD) for Product Group Seating Solution. EPD Norway, Oslo

Eurofins (2012) Eurofins. http://www.eurofins.com

Fet AM, Skaar C, Michelsen O (2009) Product category rules and environmental product declarations as tools to promote sustainable products: experiences from a case study of furniture production. Clean Technol Envir 11 (2):201-207. doi:10.1007/s10098-008-0163-6

Greenguard (2011) GREENGUARD Environmental Institute Formaldehyde Free Verification Requirement. Marietta

Guo Z (2002a) Review of indoor emission source models. Part 1. Overview. Environ Pollut 120 (3):533-549. doi: 10.1016/S0269-7491(02)00187-2

Guo Z (2002b) Review of indoor emission source models. Part 2. Parameter estimation. Environ Pollut 120 (3):551-564. doi: 10.1016/S0269-7491(02)00188-4

He G, Yang X, Shaw CY (2005) Material Emission Parameters Obtained Through Regression. Indoor Built Environ 14(1):59-68. doi: 10.1177/1420326X05050347

Hellweg S, Demou E, Bruzzi R, Meijer A, Rosenbaum RK, Huijbregts MAJ, McKone TE (2009) Integrating Human Indoor Air Pollutant Exposure within Life Cycle Impact Assessment. Environ Sci Technol 43 (6):1670-1679. doi:10.1021/Es8018176

Hun DE, Corsi RL, Morandi MT, Siegel JA (2010) Formaldehyde in residences: long-term indoor concentrations and influencing factors. Indoor Air 20 (3):196-203. doi:10.1111/j.0905-6947.2010.00644.x

International Organization for Standardization (2001) Indoor air - Part 3: Determination of formaldehyde and other carbonyl compounds - Active sampling method (ISO 16000-3:2001). International Organization for Standardization, Geneva, Switzerland

International Organization for Standardization (2004) Indoor air - Part 6: Determination of volatile organic compounds in indoor and test chamber air by active sampling on Tenax TA sorbent, thermal desorption and gas chromatography using MS/FID (ISO 16000-6:2004). International Organization for Standardization, Geneva, Switzerland

International Organization for Standardization (2006a) Environmental management - Life cycle assessment - Requirements and guidelines (ISO 14044:2006). International Organization for Standardization, Geneva, Switzerland

International Organization for Standardization (2006b) Indoor air - Part 9: Determination of the emission of volatile organic compounds from building products and furnishing - Emission test chamber method (ISO 16000-9:2006). International Organization for Standardization, Geneva, Switzerland

International Organization for Standardization (2006c) Indoor air - Part 11: Determination of the emission of volatile organic compounds from building products and furnishing - Sampling, storage of samples and preparation of test specimens (ISO 16000-11:2006). International Organization for Standardization, Geneva, Switzerland

Jørgensen RB, Bjørseth O (1999) Sorption behaviour of volatile organic compounds on material surfaces - the influence of combinations of compounds and materials compared to sorption of single compounds on single materials. Environ Int 25: 17-27. doi:10.1016/S0160-4120(98)00090-7

Jørgensen RB, Bjørseth O, Malvik B (1999) Chamber Testing of Adsorption of Volatile Organic Compounds (VOCs) on Material Surfaces. Indoor Air 9(1): 2-9. doi: 10.1111/j.1600-0668.1999.t01-3-00002.x

Jørgensen RB, Dokka TH, Bjørseth O (2000) Introduction of a sink-diffusion model to describe the interaction between VOCs and material surfaces. Indoor Air 10: 27-38. doi: 10.1016/j.buildenv.2006.03.003

Kim I, Hur T (2009) Integration of working environment into life cycle assessment framework. Int J LCA 14 (4):290-301. doi: 10.1007/s11367-009-0087-3

Kuehn BM (2008) Stronger formaldehyde regulation sought. Jama-J Am Med Assoc 299 (17):2015-2015. doi: 10.1001/jama.299.17.2015

Meijer A, Huijbregts MAJ, 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. Int J LCA 10 (5):309-316. doi:10.1065/lca2004.12.194.1

National Research Council (1991) Human exposure assessment for airborne pollutants : advances and opportunities. National Academy Press, Washington, D.C.

Nordic Ecolabelling (2011a) Nordic Ecolabelling of Furniture and fitments. Oslo

Nordic Ecolabelling (2011b) Nordic Ecolabelling of Panells for the building, decoration and furniture industries, Oslo

Office of Environmental Health Hazard Assessment (2011) Proposition 65. http://www.oehha.ca.gov/prop65/background/p65plain.html. Accessed 7 July 2011

PE International (2011) GaBi. http://www.gabi-software.com

Rosenbaum R, Bachmann T, Gold L, Huijbregts M, Jolliet O, Juraske R, Koehler A, Larsen H, MacLeod M, Margni M, McKone T, Payet J, Schuhmacher M, van de Meent D, Hauschild M (2008) USEtox—the UNEP-SETAC toxicity model: recommended characterisation factors for human toxicity and freshwater ecotoxicity in life cycle impact assessment. Int J LCA 13 (7):532-546. doi:10.1007/s11367-008-0038-4

Saarela K, Tirkkonen T (2004) M1, Emission Classification of Building Materials: Protocol for Chemical and Sensory Testing of Building Materials. VTT, Finland

Salthammer T, Mentese S, Marutzky R (2010) Formaldehyde in the Indoor Environment. Chem Rev 110 (4):2536-2572. doi:10.1021/cr800399g

Sexton K, Adgate JL, Church TR, Ashley DL, Needham LL, Ramachandran G, Fredrickson AL, Ryan AD (2005) Children's Exposure to Volatile Organic Compounds as Determined by Longitudinal Measurements in Blood. Environ Health Perspect 113(3): 342-349. doi:10.1289/ehp.7412

Sexton K, Adgate JL, Ramachandran G, Pratt GC, Mongin SJ, Stock TH, Morandi MT (2003) Comparison of Personal, Indoor, and Outdoor Exposures to Hazardous Air Pollutants in Three Urban Communities. Environ Sci Technol 38 (2):423-430. doi:10.1021/es030319u

Singer BC, Hodgson AT, Hotchi T, Ming KY, Sextro RG, Wood EE, Brown NJ (2007) Sorption of organic gases in residential rooms. Atmos Environ 41(15): 3251-3265. doi:10.1016/j.atmosenv.2006.07.056

SPSS (2010) SPSS 14.0 for Windows.
Tichenor BA, Guo Z (1991) The effect of ventilation on emission rates of wood finishing materials. Environ Int 17 (4):317-323. doi: 10.1016/0160-4120(91)90018-L
Tichenor BA, Guo Z, Dorsey JA (1992) Emission rates of mercury from latex paints. U.S. Environmental Protection Agency, Washington DC, USA
Tichenor, B.A. Guo, Z. Dunn, James E., Sparkds L.E., Mason M.A. (1991) The interaction of vapour phase organic compounds with indoor sinks. Indoor Air 1: 23-37. doi:10.1111/j.1600-0668.1991.03-11.x
USEtox (2011) USEtox™ model. http://www.usetox.org. Accessed 8 February 2011
Wenger Y, Li D, Jolliet O (2012) Indoor intake fraction considering surface sorption of air organic compounds for life cycle assessment. Int J LCA (online first). doi:10.1007/s11367-012-0420-0
Westerdahl J, Hallberg E, Öman A, Andersson PL, Haglund P, Holmgren T, Fuhrman F, Molander S, Tivander J (2012) Emissions of Additives from Plastics in the Societal Material Stock: A Case Study for Sweden. In: Bilitewski B, Darbra RM, Barceló D (ed) The Handbook of Environmental Chemistry Volume 18. Springer, Berlin, pp 133-149. doi:10.1007/698_2011_107
WHO (2010) WHO guidelines for indoor air quality: selected pollutants. The WHO European Centre for Environment and Health, Bonn, Germany
Øie L (1998) The ventilation rate of 344 Oslo residences. Indoor Air 8 (3):190-196. doi: 10.1111/j.1600-0668.1998.t01-1-00006.x

Figure captions

Fig. 1: Integrating indoor emissions into LCA

Fig. 2: Impacts in the use phase over 15 and 70 years for three emission models, with variation in intake fraction (low iF, Nordic average iF and high iF) and a furniture replacement frequency of 15 years

Fig. 3: Impacts in the use phase over 70 years for six different furniture replacement frequencies (three emission models, with Nordic iF)

Fig. 4: Emission of formaldehyde from furniture, 1 month [µg/h]

Fig. 5: Emission of formaldehyde from furniture, 1 year [µg/h]

Fig. 6: Significance of furniture replacement frequency on impact in a 30 year perspective with Nordic intake fraction

Figures

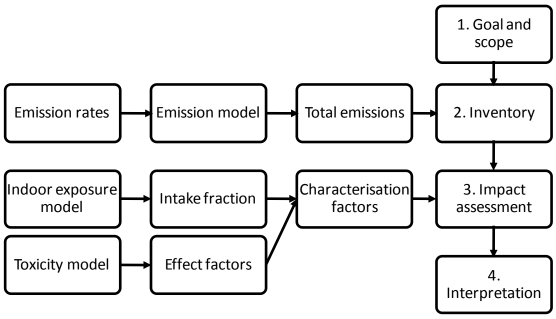


Fig. 1

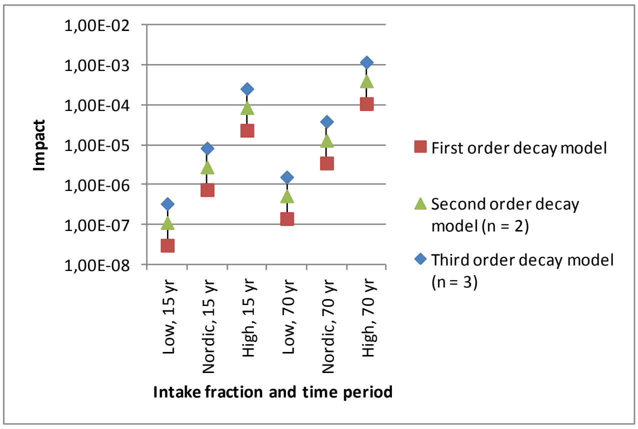


Fig. 2

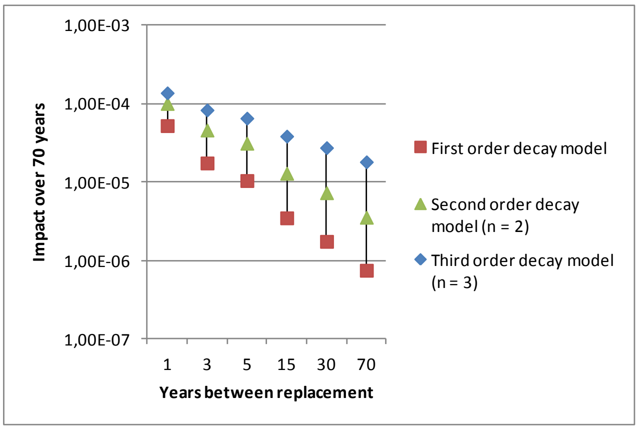
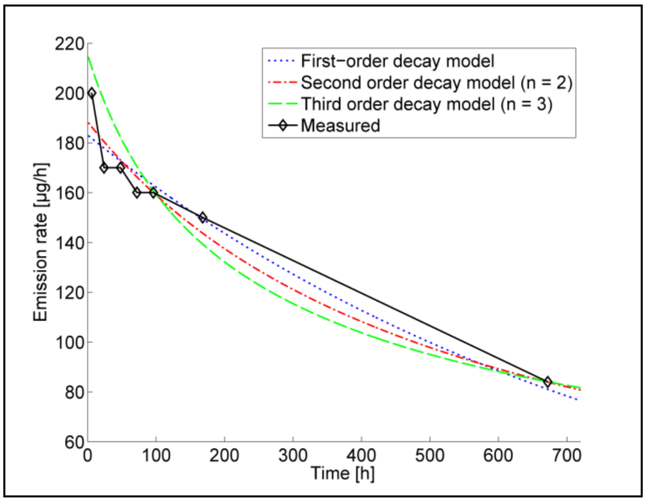
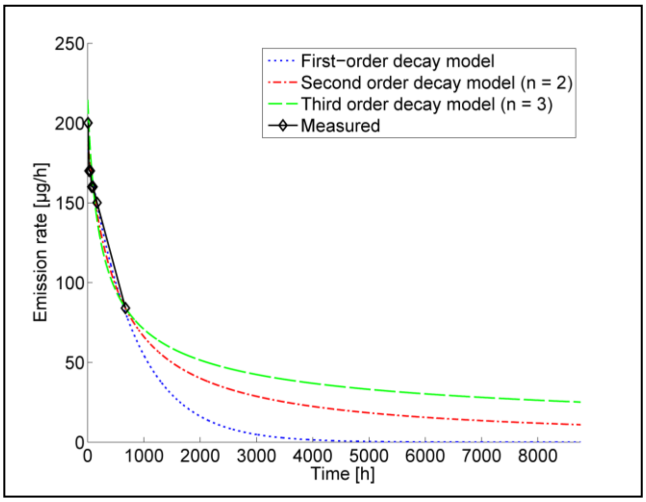


Fig. 3



First−order decay model
Second order decay model (n = 2)
Third order decay model (n = 3)
Measured
Emission rate [µg/h]
Time [h]
220
200
180
160
140
120
100
80
60
0
100
200
300
400
500
600
700

Fig. 4



First−order decay model
Second order decay model (n = 2)
Third order decay model (n = 3)
Measured
Emission rate [µg/h]
Time [h]
250
200
150
100
50
0
1000
2000
3000
4000
5000
6000
7000
8000

Fig. 5

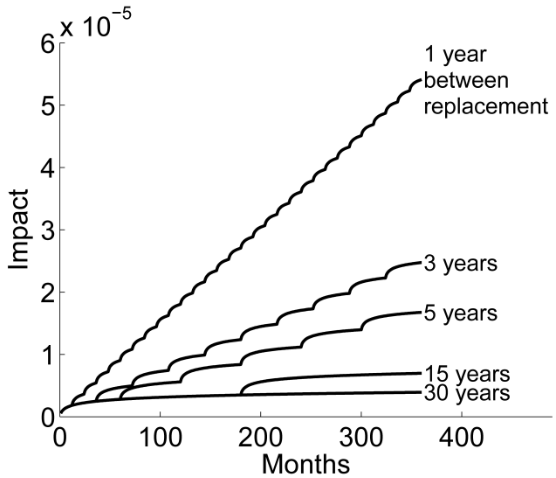

x 10^−5
Impact
Months
1 year
between
replacement
3 years
5 years
15 years
30 years
0
1
2
3
4
5
6
0
100
200
300
400

Fig. 6

Supplementary Material

Table S1: Measured emission rates

Substance	Emission rate at specified hour [µg/h]						
	6	**24**	**48**	**72**	**96**	**168**	**672**
formaldehyde	200	170	170	160	160	150	84
acetaldehyde	30	11	5.9	5	0	0	0
Propionaldehyde	33	15	0	0	0	0	0
TVOC (AgBB/RAL UZ117)	*3900*	*3500*	*3100*	*2800*	*2800*	*2000*	*760*
TVOC as toluene equiv.	*2200*	*1900*	*1700*	*1600*	*1600*	*1200*	*470*
TVVOC	*13*	*5.5*	*3.5*	*4*	*3.8*	*3.1*	*0*
Acetone	31	16	10	12	11	9	0
Butanal	9.2	4.6	3.2	2.5	3.7	24[b]	0
iso-Butanol	1000	850	710	600	560	310	0
1-Butanol	1100	970	840	740	710	470	110
1-Methoxy-2-propanol	140	130	130	110	120	83	16
2-Ethoxy-1-ethanol	58	0	54	50	51	39	12
Toluene	13	8.7	5.9	4.6	3.2	2.5	0
Hexanal	39	25	27	19	20	16	7.9
Butyl acetate	180	130	98	77	69	38	9.4
Diacetone alcohol	2.9	0[b]	3	2.9	2.8	2.3	0
Ethylbenzene	6.9	4.9	3.9	3.2	2.9	2.2	0
p-/m-Xylene	17	12	10	8.3	0	0	0
Cyclohexanone	17	15	13	11	11	8.3	0
Styrene	3.9	2.8	2.4	0	0	0	0
o-Xylene	6.6	4.9	4.1	3.4	3.4	2.6	0
2-Butoxyethanol	570	0[b]	610	580	600	500	260
Benzaldehyde	13	14	11	11	9.9	9.1	6.2
n-Decane	5.2	4.2	3.8	0[b]	3.4	2.8	0
Benzyl alcohol	66	72	78	74	78	72	51
1,4-Dichlorobenzene	6.7	6.2	5.4	5.2	5.7	4.9	0
2-Ethyl-1-hexanol	44	42	41	38	41	34	17
Limonene	5.1	3.9	3.7	3.4	3.8	2.7	0
n-Undecane	13	9.9	9.3	6.3	8.9	4.5	0
2-Ethylhexyl acetate	280	230	210	200	220	190	97
n-Dodecane	8.6	6.8	6.5	5.9	6.5	5.6	2.5
n-Tridecane	5.2	4.2	3.9	3.8	4	3.7	0
n-Tetradecane	2.1	0	0	0	0	2	0
Butylhydroxytoluene	26	24	25	22	24	32	19
Sum of not identified VOC[c]	280	200	200	180	200	150	26

a) Substances tested for but not included in table (either all zero or a single value in the series): Butyraldehyde, TSVOC, 1-Hexadecene

b) Anomalous value, excluded from regression analysis

c) 4 not identified sub-totals not included in table

The emissions of *TVOC (AgBB/RAL UZ117), TVOC as toluene equiv*. and *TVVOC* are not included in the calculations, as this would lead to double counting. The emission of *Sum of not identified VOC* is not included in the general assessment, but is included in the evaluation of effect factors.

Table S2: Goodness of fit, R2 for 5 emission rate models

Substance	R^2 for 5 emission rate models				
	First order	**Double first order**	**n=2**	**n=2.5**	**n=3**
formaldehyde	0.94	0.94	0.95	0.95	0.84
acetaldehyde	0.97	0.98	0.98	0.94	0.84
Propionaldehyde	0.98	0.98	0.93	0.85	0.73
TVOC (AgBB/RAL UZ117)	0.96	0.97	0.93	0.85	0.87
TVOC as toluene equiv.	0.96	0.96	0.94	0.93	0.82
TVVOC	0.77	0.79	0.92	0.95	0.96
Acetone	0.78	0.79	0.90	0.93	0.94
Butanal	0.84	0.84	0.92	0.94	0.94
iso-Butanol	1.00	0.93	0.95	0.94	0.88
1-Butanol	0.99	0.94	0.96	0.95	0.88
1-Methoxy-2-propanol	0.98	0.98	0.93	0.89	0.86
2-Ethoxy-1-ethanol	0.99	0.99	0.95	0.92	0.88
Toluene	0.97	0.97	0.99	0.98	0.96
Hexanal	0.77	0.79	0.89	0.92	0.93
Butyl acetate	0.97	0.98	1.00	0.96	0.97
Diacetone alcohol	0.92	0.00	0.81	0.75	0.71
Ethylbenzene	0.95	0.95	0.98	0.97	0.96
p-/m-Xylene	0.91	0.91	0.85	0.81	0.77
Cyclohexanone	0.99	0.99	0.95	0.92	0.89
Styrene	0.89	0.89	0.81	0.76	0.72
o-Xylene	0.95	0.95	0.96	0.95	0.93
2-Butoxyethanol	0.94	0.94	0.90	0.88	0.58
Benzaldehyde	0.00	0.00	0.87	0.90	0.92
n-Decane	0.97	0.97	0.92	0.90	0.87
Benzyl alcohol	0.69	0.69	0.66	0.65	0.64
1,4-Dichlorobenzene	0.93	0.93	0.84	0.80	0.77
2-Ethyl-1-hexanol	0.98	0.98	0.97	0.95	0.93
Limonene	0.94	0.94	0.89	0.86	0.83
n-Undecane	0.92	0.92	0.90	0.88	0.86
2-Ethylhexyl acetate	0.88	0.88	0.70	0.78	0.75
n-Dodecane	0.89	0.89	0.91	0.91	0.91
n-Tridecane	0.91	0.91	0.83	0.80	0.76
n-Tetradecane	0.00	0.00	0.72	0.67	0.63
Butylhydroxytoluene	0.22	0.00	0.21	0.21	0.20
Sum of not identified VOC[c]	0.92	0.22	0.74	0.80	0.85

Table S3: USEtox effect factors compared against LCI values from ECA, AgBB and AFSSET

Substance	CAS	USEtox Effect Factors (EF)		Comparison
		$EF_{canc.}$	$EF_{non-canc.}$	LCI[a] [µg/m3]
formaldehyde	50-00-0	1.061307	0.008471	10
acetaldehyde	75-07-0	0.007492	0.038451	40
Propionaldehyde	123-38-6	n/a[b]	n/a	8
TVOC (AgBB/RAL UZ117)		not included	not included	-
TVOC as toluene equiv.		not included	not included	-
TVVOC		not included	not included	-
Acetone	67-64-1	n/a	0.000282	30800
Butanal	123-72-8	n/a	n/a	400
iso-Butanol	78-83-1	n/a	0.000804	1000
1-Butanol	71-36-3	n/a	0.002033	1000
1-Methoxy-2-propanol	107-98-2	n/a	0.000508	2000
2-Ethoxy-1-ethanol	110-80-5	n/a	0.004919	8
Toluene	108-88-3	0	0.003636	300
Hexanal	66-25-1	n/a	n/a	400
Butyl acetate	123-86-4	n/a	n/a	4800
Diacetone alcohol	123-42-2	n/a	n/a	950
Ethylbenzene	100-41-4	0.023585	0.000385	750
p-/m-Xylene	1330-20-7	0.000369	0.008577	200
Cyclohexanone	108-94-1	0	0.000275	410
Styrene	100-42-5	0.049194	0.009839	70
o-Xylene	95-47-6	n/a	n/a	200
2-Butoxyethanol	111-76-2	0.001193	0.007923	980
Benzaldehyde	100-52-7	0.00137	0.001777	90
n-Decane	124-18-5	n/a	n/a	2000
Benzyl alcohol	100-51-6	0	n/a	440
1,4-Dichlorobenzene	106-46-7	0.007531	0.00223	60
2-Ethyl-1-hexanol	104-76-7	0.001215	n/a	1000
Limonene	138-86-3	n/a	n/a	450
n-Undecane	1120-21-4	not found	not found	6000
2-Ethylhexyl acetate	103-09-3	not found	not found	200
n-Dodecane	112-40-3	not found	not found	6000
n-Tridecane	629-50-5	not found	not found	6000
n-Tetradecane	629-59-4	not found	not found	6000
Butylhydroxytoluene	128-37-0	0.003125	n/a	100
Sum of not identified VOC[c]	50-00-0	not found	not found	-

a) Evaluation of substances against the lowest concentration of interest (LCI) in three air quality evaluation schemes: ECA 1997, AgBB 2008, AgBB 2010 and AFSSET 2009. LCI values are used in risk-based health evaluations of VOC emissions from building products. Where there are differences in the LCI between the three schemes, the lowest value of the three is used.
b) n/a = not applicable

Table S4: Impacts in the use phase, 70 years

		Indoor exposure [CTU]			Outdoor exposure [CTU]		
iF	Years between replacement	First order	$n = 2$	$n = 3$	First order	$n = 2$	$n = 3$
0.00018 (low)	1	2.13E-06	4.10E-06	5.58E-06	2.85E-07	5.48E-07	7.45E-07
	3	7.11E-07	1.88E-06	3.38E-06	9.50E-08	2.51E-07	4.52E-07
	5	4.27E-07	1.27E-06	2.66E-06	5.70E-08	1.70E-07	3.55E-07
	15	1.42E-07	5.28E-07	1.57E-06	1.90E-08	7.05E-08	2.10E-07
	30	7.11E-08	2.97E-07	1.12E-06	9.50E-09	3.97E-08	1.50E-07
	70	3.05E-08	1.45E-07	7.38E-07	4.07E-09	1.93E-08	9.86E-08
0.0045 (Nordic)	1	5.27E-05	1.01E-04	1.38E-04	2.84E-07	5.46E-07	7.41E-07
	3	1.76E-05	4.63E-05	8.35E-05	9.46E-08	2.49E-07	4.50E-07
	5	1.05E-05	3.14E-05	6.56E-05	5.67E-08	1.69E-07	3.54E-07
	15	3.51E-06	1.30E-05	3.87E-05	1.89E-08	7.02E-08	2.09E-07
	30	1.76E-06	7.34E-06	2.76E-05	9.46E-09	3.95E-08	1.49E-07
	70	7.53E-07	3.57E-06	1.82E-05	4.05E-09	1.93E-08	9.82E-08
0.1387 (High)	1	1.62E-03	3.12E-03	4.24E-03	2.45E-07	4.72E-07	6.42E-07
	3	5.41E-04	1.43E-03	2.57E-03	8.18E-08	2.16E-07	3.89E-07
	5	3.25E-04	9.66E-04	2.02E-03	4.91E-08	1.46E-07	3.06E-07
	15	1.08E-04	4.02E-04	1.19E-03	1.64E-08	6.08E-08	1.81E-07
	30	5.41E-05	2.26E-04	8.52E-04	8.18E-09	3.42E-08	1.29E-07
	70	2.32E-05	1.10E-04	5.62E-04	3.51E-09	1.67E-08	8.49E-08

Table S5: Impacts in the use phase, 15 years

		Indoor exposure [CTU]			Outdoor exposure [CTU]		
iF	Years between replacement	First order	$n = 2$	$n = 3$	First order	$n = 2$	$n = 3$
0.00018 (low)	1	4.57E-07	8.79E-07	1.19E-06	6.11E-08	1.17E-07	1.60E-07
	3	1.52E-07	4.02E-07	7.25E-07	2.04E-08	5.37E-08	9.68E-08
	5	9.15E-08	2.72E-07	5.70E-07	1.22E-08	3.64E-08	7.61E-08
	15	3.05E-08	1.13E-07	3.36E-07	4.07E-09	1.51E-08	4.49E-08
0.0045 (Nordic)	1	1.13E-05	2.17E-05	2.95E-05	6.08E-08	1.17E-07	1.59E-07
	3	3.76E-06	9.92E-06	1.79E-05	2.03E-08	5.34E-08	9.63E-08
	5	2.26E-06	6.72E-06	1.41E-05	1.22E-08	3.62E-08	7.58E-08
	15	7.53E-07	2.79E-06	8.30E-06	4.05E-09	1.50E-08	4.47E-08
0.1387 (High)	1	3.48E-04	6.69E-04	9.09E-04	5.26E-08	1.01E-07	1.37E-07
	3	1.16E-04	3.06E-04	5.51E-04	1.75E-08	4.62E-08	8.34E-08
	5	6.96E-05	2.07E-04	4.33E-04	1.05E-08	3.13E-08	6.56E-08
	15	2.32E-05	8.61E-05	2.56E-04	3.51E-09	1.30E-08	3.87E-08

Table S6: LCA of a chair, excluding the use phase

Impact category	Production	Disposal	Total
Acidification Potential [kg SO2-Equiv.]	2.82E-01	3.03E-01	5.85E-01
Eutrophication Potential [kg Phosphate-Equiv.]	5.65E-02	6.16E-02	1.18E-01
Freshwater Aquatic Ecotoxicity Pot. [kg DCB-Equiv.]	3.44E-01	7.57E-01	1.10E+00
Global Warming Potential [kg CO2-Equiv.]	4.20E+01	6.66E+01	1.09E+02
Human Toxicity Potential [kg DCB-Equiv.]	1.73E+00	1.80E+00	3.53E+00
Marine Aquatic Ecotoxicity Pot. [kg DCB-Equiv.]	3.80E+03	3.91E+03	7.71E+03
Ozone Layer Depletion Potential [kg R11-Equiv.]	1.01E-06	1.07E-06	2.08E-06
Photochem. Ozone Creation Potential [kg Ethene-Equiv.]	1.79E-01	1.80E-01	3.59E-01
Terrestric Ecotoxicity Potential [kg DCB-Equiv.]	3.45E-02	3.53E-02	6.98E-02
USETox2008, Ecotoxicity [PAF m3.day]	7.24E-02	7.69E-02	1.49E-01
USETox2008, Human toxicity [cases]	4.17E-09	4.20E-09	8.37E-09

Appendix 7

Product-Category Rules (PCR) for preparing an Environmental Product Declaration (EPD) for Product Group Seating solution. NPCR 003 Revised version.

epd-norge.no
The Norwegian EPD Foundation

PRODUCT-CATEGORY RULES (PCR)

for preparing an Environmental Product Declaration (EPD) for Product Group

Seating solution

NPCR 003

Revised version

epd-norge.no
The Norwegian EPD Foundation

Glossary

Declared unit:
Quantity of a building product for use as a reference unit in an environmental declaration for the full life cycle of the product [ISO 21930: 2004,. ISO 14025, 2006]

Functional unit:
Quantified performance of a product system for use as a reference unit in an life cycle assessment study [ISO 14040:2006 and ISO 14025, 2006]

Hazardous waste:
Waste substances that can pose a hazard to human health or the environment, as defined in to EU Directives 91/689/EEC and 75/442/EEC.

Impact category:
Class representing environmental issues of concern into which LCI results may be assigned [ISO 14044:2006]

Life Cycle:
Consecutive and interlinked stages of a product system, form raw material acquisition or generation of natural resources to the final disposal [ISO 14040:2006]

Life cycle inventory (LCI): phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout the life cycle [ISO 14044: 2006]

Life cycle assessment (LCA):
Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle [ISO 14040:2006]

Non-renewable resource:
Resource that exists in an fixed amount in various places in the earth's crust and that cannot be replenished on a human time scale. [ISO 21930: 2007]

Product Category Rules (PCR):
Set of specific rules, requirements, and guidelines for developing Type III environmental declarations for one or more products categories [ISO 14025, 2006]

Renewable resource:
Resource that is grown naturally replenished or cleansed on a human time scale. [ISO 21930: 2007]

System boundary:
Interface between a product system and the environment or other product systems [ISO14040:2006]

epd-norge.no
The Norwegian EPD Foundation

Contents

1 GENERAL INFORMATION

The content of this PCR for seating solutions is based on NPCR003, published 2005-10-14, and prepared by Norwegian University of Science and Technology (NTNU), Helland Møbler AS, J.E.Ekornes ASA, Håg AS, Jensen Møbler AS. Contact person is Christofer Skaar. The restructuring of this PCR-document is prepared, in accordance with ISO 14025: 2006, by Annik Magerholm Fet and Christofer Skaar at NTNU.

The content of Chapter 7 on impacts from chemicals is provided by Rikke Jørgensen, Kristin Svendsen and Uno Abrahamsen at NTNU.

2 DEFINITION OF PRODUCT CATEGORY GROUP

These Product Category Rules are intended for seating solution, a subcategory of furniture. The rules apply to products that provide the function of seating. Other functions that the product may provide are not considered herein.

This document specifies the requirements for the LCA study and for the format and content of the EPD itself. Recognising the global aspects of the furniture industry, the geographical coverage is global.

The product or range of products will be identified by the number of seating solutions provided and the guaranteed lifetime of the main product(s).

In accordance with the "Requirements for an International EPD scheme", similar products (i.e. products with different textiles, surface treatments, foam type, etc.) can be included in the same declaration, provided that the range of variation within each impact category does not exceed ±5 %. The relevant impact categories are listed in section 5.

3 LCA-BASED INFORMATION

The environmental declaration for seating solution shall include information from each of the life cycle stages: "Production", "Use in building", "Disassembling" and "End of life treatment". If information on any of these life cycle stages is missing, this shall be clearly stated in the EPD.

3.1 Definition of functional unit

The functional unit for the life cycle assessment is one seating solution provided and maintained for a period of 15 years.

The EPD shall provide information for the entire physical product.

3.2 System boundaries

The entire life cycle shall be covered. This includes all industrial processes from raw material extraction and production, use and maintenance, dismantling, transportation, and disposal. Rules on how recycling processes should be handled are described in Chapter 4.3 Allocation Rules.

The boundaries towards nature shall describe the flow of material and energy resources from nature into the system and emissions from the system to air and water, and waste.

The boundaries towards other technical systems describe the inflow of material and components from other systems, and the outflow of material to other systems.

The flow chart of the processes for seating solution is illustrated in Figure 1. The system boundaries may appear partly different for the different product types, and must be described or illustrated in the EPD. Figure 1 can be used as a model to illustrate the flow chart for the actual product type.

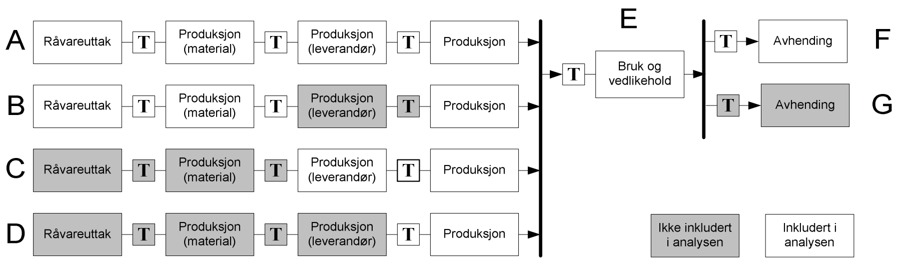


Figure 1 – Flow chart of system boundaries.

If the EPD does not cover the entire life cycle (cradle to grave, shown as units AEF in Figure 1), this shall be clearly stated at the front page of the EPD. Alternative statements for the following system boundaries are:

AEF: This declaration covers environmental impacts throughout the product life cycle, from raw material extraction to and including product disposal.

AE: This declaration covers environmental impacts from raw material extraction to use and maintenance. The declaration does not cover product disassembly or disposal, and is therefore not comparable to declarations that cover the entire product life cycle.

A: This declaration covers environmental impacts from raw material extraction to production. The declaration does not cover use and maintenance or product disposal, and is therefore not comparable to declarations that cover the entire product life cycle.

D: This declaration is a module environmental product declaration. It covers only the main production process of the product. Raw material extraction and production, use and maintenance, and disposal, are not included.

Building of site, infrastructure and production of manufacturing equipment and personnel activities shall not be included, nor is biological CO_2 consumptions and emissions included within the system boundaries.

3.3 Description of data

The environmental background information in this PCR has been prepared based on experiences with a national furniture database [1] and previously performed life cycle assessments of seating solutions [2], [3].

For the supplement of data, specific data should be prioritized. In the absence of other specific data, data from databases can be used as specific data if the following rules are demonstrated:

1. representativeness of the geographical area

2. technological equivalence
3. boundaries towards nature equivalence
4. boundaries towards technical systems equivalence (e.g. allocation rules)

The demonstration of the compliance to these 4 rules shall be clearly described in the technical report from the LCA-study, or in the report on environmental background information. The data sources have to be documented, including the database and the year of publication. This requirement also encompasses sources of data for transport models (including transport form, distances and quantities to be transported), and thermal energy production shall be documented.

The EPD should give information about the databases that are used, and if possible, information about national databases in the country where the components are produced. Appendix 1 gives an overview of relevant databases to be used for generic data.

3.4 Criteria for inclusion of inputs and outputs, and data quality requirements

Input and output data must be gathered based on instructions in Chapter 4.

Inputs or outputs in the use and maintenance phases must be considered. Examples of relevant in- and outputs for use and maintenance are: detergents, water and energy for cleaning (heating water, vacuuming). The life cycle of such items must be addressed (this means that separate LCA-data for such items must be available). The same requirements as described under Chapter 4.1 should be applied here.

3.5 Units

The following units shall be used:

- SI units for both the LCA and the EPD
- Preferred power and energy units:
  - kW for power
  - kWh (MJ) for energy

4 INVENTORY ANALYSIS

4.1 List of materials and chemical substances

The materials and substances listed below must be reported in the environmental product declaration (EPD).

Product specification:

- Material composition, in kg per functional unit and in percentage of total weight.
- Product content of hazardous substances, e.g.:
  - Formaldehyde
  - Brominated flame retardants
  - Heavy metals (specified), e.g. Hg, Pb, Ni, Cr(VI), Cd
- All materials representing 2 per cent or more by weight.
- All materials/substances that are hazardous to health or the environment, allergenic, carcinogenic, mutagenic, toxic to reproduction or dangerous for the environment if present in such a concentration in the product that it meets requirements for being subject to labelling. The current directives on hazard classification and labelling; 67/548/EEC (Dangerous Substance Directive) and 1999/45/EC (Dangerous Preparation Directive) are replaced by a new Regulation, EC 1272/2008 for Classification, Labelling and Packaging of Substances and Mixtures (CLP), which entered into force in EU in January 2009. CLP is based on UN's recommended

Globally Harmonised System of Classification, labelling and Packaging of Substances and Mixtures (known as GHS), which aims to have a worldwide harmonised classification and communication for hazardous chemicals.

4.2 Data collection and calculation procedures

Information and data to be presented in an EPD shall be based upon an LCA-study or equivalent. Data collection and calculation procedures shall therefore follow instructions given in ISO 14040: 2006 and ISO 14044: 2006.

Data must be collected for inputs and calculated or measured for outputs.

Typical input data are material resources and energy resources. Resources can be classified as natural resources or secondary (alternative/recycled) resources, and sorted as non-renewable and renewable. Resources are further grouped as material resources (e.g. main raw materials, water, fossil fuels in kg) and energy resources (e.g. fossil fuels in MJ/kWh). Resources with mass and energy content, e.g. fossil fuels, will be presented in both groups.

(Raw) Materials
Appendix 2 lists the most relevant materials used in seating solutions.

The quantities (kg) of (raw) materials must be specified.
They are grouped as

- Metals
- Textiles and leather
- Plastics
- Coating
- Wood
- Packaging materials
- Other materials

Energy consumption:

- Energy consumption (specified as renewable or non-renewable) in the different life cycle stages (kWh or MJ). The mix of electricity used in the production process or during the use of the product shall primarily be used. If specific data cannot be obtained, the official mix in the country where the main energy consuming processes take place should be used. The mix of electricity (calculation procedure) shall be documented.

Water/Air:

- Water (m^3) if used in the production. If water is omitted, this must be justified and documented.

Transport:

- Transport is counted in terms of the capacity (%) of the vehicles (trucks, trains, ships) and the length of the routes travelled (km).

Other incoming materials must be specified separately, see 3.4.

Typical output data are finished products, by-products, wastes (e.g. hazardous and non-hazardous waste) and emissions generated during production processes, during transportation, use and maintenance, and from end-of life treatment of the products. For contribution to environmental impact categories, see chapter 5 and 7.

For simplicity, LCA data tools[1] are recommended to be used in the calculation.

4.3 Cut off criteria

Processes and activities that contribute to more than 1% of the total environmental impact for each impact category must be included in the inventory. Omissions from the inventory must be documented and justified based upon available information.

4.4 Allocation rules

Where possible, allocation should be avoided by dividing unit processes shared with other product systems into two or more sub-processes (as specified in ISO 14044, pp 20-22). If allocation cannot be avoided, the following allocation methods are preferred:

- Multi-input processes: Allocation based on physical relationships (i.e. mass balances).
- Multi-output processes: Allocation based on the economic relationships between the output products.
- Open loop recycling: No allocation should be made for materials subject to recycling. The recycling processes and transport to the manufacture site are included when recycled materials are used as inputs. Outputs subject to recycling are regarded as inputs to the next life cycle. Only the transport to the recycling site shall charge the system when materials are subjected to recycling.

Deviation from these allocation rules must be documented and justified.

5 IMPACT CATEGORIES AND CALCULATION PROCEDURES

The EPD shall report on the contribution to the following environmental impact categories listed in Table 1 (see also Chapter 8.2):

Table 1 Environmental Impact categories

Impact category	**Unit**
Climate change (*Global warming potential, GWP)*	kg CO_2 equiv
Depletion of the stratospheric ozone layer *(Ozone Depletion Potential, ODP)*	kg CFC 11 equiv
Acidification of land and water sources *(Acidification Potential, AP)*	kg SO_2 equiv
Eutrophication (*Nutrition Potential, NP)*	kg PO_4 equiv
Formation of photochemical oxidants *(Photochemical oxidant creation potential, POCP)*	kg C_2H_4 equiv

The calculation procedures for the contribution to the impact categories shall follow the instructions given in the ISO 14044 standard, and the results shall be clearly documented in the LCA technical report, or report on environmental background information.

[1] Use of GaBi, SimpaPro, Umberto etc.

Appendix 1 to this PCR gives an overview of relevant methods and the procedures for the calculation of the contribution to the different environmental impact categories. The contribution to each impact categories shall be given by units listed in table 1.

Waste generation is another impact category, and the waste should be classified into non-hazardous and hazardous waste. The categories of hazardous waste and non-hazardous waste are based upon LCI (life cycle inventory), see clause 3.3 in ISO 14044:2006, including inflows and outflows for each of the product types.

6 PARAMETERS IN THE UNDERLYING LCA REPORT

The parameters listed in 4.1, 4.2 and 5 shall be included in the underlying LCA report. This report must also include a complete list of components analyzed in the LCA.

7 OTHER INFORMATION (VOLUNTARY)

7.1 Chemicals

The specified rules in the previous sections are intended to secure that all relevant environmental impact information will be documented in the EPD. Other information that can be represented on a voluntary basis in the EPD is specifications of materials and substances that can adversely affect human health and the indoor environment in all stages of the life cycle.

A detailed list of components in the product and intermediary chemicals used in the manufacturing process can be included in the product content declaration, including names, identification number and hazard class(es). The content of substances shall be declared by weight %. In cases where information on content could affect patent or business secrets, a qualitative list of chemicals and their expected functions is sufficient, including the hazard classification.

The chemical impact categories are grouped as follows:

- Health impacts in the production stage.
- Environmental impact in the production stage.
- Indoor environment impacts in the use phase.

The method for calculating the health impact and environmental impact and indoor environmental impact are described in Appendix 3.

7.2 Recycling declaration

A recycling declaration may include information on aspects that are important for the understanding and appreciation of the recycling properties of the product. The recycling declaration may also include information about the dismantling of products and reuse of materials.

7.3 ***Other relevant information***

Other relevant information may cover the technology used, manufacturing and assembly locations (if several), fuel origin and use, delivery aspects and other factors such as visual impact and noise. Specific information that is known to be of interest to customers can be included in this section. This can be related to risk, product handling during service and maintenance or how to reduce environmental impact during the use of the product. It is also possible to include information about the product's compliance with environmental information systems such as eco-labelling and information concerning health, safety and ergonomics. Information about the company's fulfilment or breach of laws and prescriptions may also be included.

8 CONTENT OF THE ENVIRONMENTAL DECLARATION (EPD)

All Type III environmental declarations in this product category shall follow the format and include the parameters identified in this PCR.

8.1 General information to be declared

The following general information shall be declared:

- the name and address of the manufacturer(s);
- description of the building product's use an the functional or declared unit of the building product to which the data relates;
- product identification by name (including e.g. production code) and a simple visual representation of the building product to which the EPD is developed;
- the description of the product's use and the functional or declared unit of the product to which the data relates;
- the description of the application (installation) of the windows and doors;
- a general specification for the composition of the products shall be given;
- name of the programme and the programme operator's address and, if relevant the logo and website;
- the PCR identification;
- the date the declaration was issued and period of validity;
- additional environmental information;
- a statement of whether the declaration is complete or modular; (ISO 21930:2007);
- a statement that environmental declarations from different programmes (ISO 14025:2006) may not be comparable;
- a statement that this declaration represents an average performance, in such cases where an EPD declares an average performance for a number of products. In addition the standard deviation of the products' performance with respect to the average is stated;
- the site(s), manufacturer or group of manufacturers or those representing them for whom the results of the LCA are representative;
- information on where explanatory material may be obtained;
- in addition to the above, table 3 shall be completed and reproduced in the Type III environmental declaration;

Table 3 Demonstration of verification

PCR review, was conducted by: < name and organization of the chair, and information on how to contact the chair through the programme operator >
Independent verification of the declaration and data, according to ISO 21930:2007 ☐ internal ☐ external
(Where appropriate [a]) Third party verifier: <name of the third party verifier>

a Optional for business to business communication, mandatory for business to consumer communication.

- a diagram of the product's life cycle stages the EPD represents, subdivided into product stages "Raw material production", "Transport", "Production", "Use" and "Disposal";

If the EPD does not cover the entire life cycle this shall be clearly stated on the front page of the EPD. Alternative statements can be:

- This declaration covers environmental impacts throughout the product life cycle, from raw material extraction to product disposal.
- This declaration covers environmental impacts from raw material extraction to use and maintenance. The declaration does not cover product disposal, and is therefore not comparable to declarations that cover the entire product life cycle.
- This declaration covers environmental impacts from raw material extraction to production. The declaration does not cover use and maintenance or product disposal, and is therefore not comparable to declarations that cover the entire product life cycle.
- This declaration is a module environmental product declaration. It covers the main production process of the product. Raw material extraction and production, use and maintenance, and disposal are not included.

8.2 Parameters to be declared

The information to be declared in the EPD must be specified per functional unit.

Parameters to be declared are:

Input data according to Inventory analysis, see Chapter 4.

Depletion of non-renewable energy can be differentiated into:

- Fossil oil
- Natural gas
- Coal
- Uranium

Use of renewable energy can be differentiated into:

- Hydropower
- Wind power/Solar power
- Biomass

Output information presented as contribution to the environmental impact categories presented in Table 1 in Chapter 5 and the largest emissions (by mass) to air and water.

Wastes:
Non hazardous waste (kg).
Hazardous waste (kg) according to relevant legislation (e.g. EU Directives 91/689/EEC and 75/442/EEC, and national regulations).
Waste streams based on "End of life treatment scenarios"

epd-norge.no
The Norwegian EPD Foundation

9 REFERENCES

1. Fet, A.M., Skaar, C. and Riddervold, B., 2006. Miljødatabase og miljødeklarasjoner for møbler. Report 1/2006. In Industrial Ecology Programme Report Series, Norges Teknisk Naturvitenskapelige Universitet (NTNU), Trondheim.
2. Dahlsrud, A., Fet, A.M., Emilsen, M., Nielsen, M.W., 2002a. Teknisk rapport for livsløpsanalyse av stolen Mio IV. Working paper IØT 2/02. Institutt for industriell økonomi og teknologiledelse (IØT). Norges Teknisk Naturvitenskapelige Universitet (NTNU). Trondheim.
3. Dahlsrud, A., Fet, A.M., Skjellum, M., 2002b. Teknisk rapport for livsløpsanalyse av stolen Bris., Working Paper IØT 3/02. Institutt for industriell økonomi og teknologiledelse (IØT), Norges Teknisk Naturvitenskapelige Universitet (NTNU). Trondheim.
4. ISO 14025:2006, Environmental labels and declarations, Type III Environmental Declarations
5. ISO 21930 :2007 Building construction – Sustainability in building construction - Environmental declaration of building products
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 14001:2004 Environmental management system requirements
9. ISO 9001: 2000 Quality management system requirements

Waste treatment:

10. EU directives, 91/689/EEC and 75/442/EE (see also regulation of June 1, 2004 no. 930 of recycling and treatment of waste with amendment by the Ministry of the Environment 2. May 2005 (avfallsforskriften)).
11. RoHS-directive 2002/95/EC - Restriction of Hazardous Substances Directive (RoHS) Er dette relevant da det gjelder elektrisk og elektroniske produkter!

Additional national standards and documents to be specified or referred to in the declaration, if relevant:

12. ISPM 15 Internasjonal plantesanitær standard for pakkemateriale
13. BS 476 part 22: Clause 6. Fire test
14. EN 1634-1 Fire test
15. DIN 18273: 1995-09 bzw. 1997-12 Fire test / Certificate
16. EN 61000-6-1, EMC test / conformity
17. EN 61000-6-2, EMC test / conformity
18. EN 61000-6-3, EMC test / conformity
19. EN 61000-6-4, EMC test / conformity

Approved 15.10.2008, valid until 15.10.2011

Norwegian EPD Foundation, PCR Review Panel

Sunne Fossdal

Appendix 1: Databases and calculation procedures.

Table A1-1: Databases for materials

Material	Database	Published
Steel	IISI (International Iron and Steel Institute) http://worldsteel.org	1998 or newer updates
Copper	ICA (International Copper Association)	1998 or newer updates
Copper semi products	ICA (International Copper Association) + IME (Institut für Metallhüttenwesen und Elektrometallurgi, Aachen)	1995 or newer
Electricity	ETH (Eidgenössische Technische Hochschule) data combined with IEA (International Energy Agency) statistics	1998 or newer
Brass	http://www.brass.org/	
Aluminium	EAA (European Aluminium Association) http://www.eaa.org/	2005
Plastics	Plastics Europe (Association of Plastics Manufacturers Europe) http://www.plasticseurope.org/	1993-1998 or newer updates
Chemicals	Plastics Europe (Association of Plastics Manufacturers Europe) http://www.plasticseurope.org/	1993-1998 or newer updates
Electronic components	EIME (Environmental Information and Management Explorer) EcoBilan	1998 or newer
-	ELCD (European Reference Life Cycle Data System)	2007 or newer

The EcoInvent LCA-database also include infrastructure, and thereby a more comprehensive database. This database can be used if infrastructure is excluded. Other generic databases can be used if they fulfil the data quality requirements in chapter 3.

Table A1-2 Information about sources for calculation of contributions to impact categories

Impact category	Unit	Source for the calculation procedures
Climate change (*Global warming potential (GWP)*)	[kg CO_2 equiv]	CML 2001
Depletion of the stratospheric ozone layer) *(Ozone Depletion Potential (ODP))*	[kg CFC 11 equiv]	CML 2001
Acidification of land and water sources *(Acidification Potential (AP))*	[kg SO_2 equiv]	CML 2001
Eutrophication (*Nutrition Potential (NP)*)	[kg PO_4 equiv]	CML 2001
Formation of photochemical oxidants *(Photochemical oxidant creation potential (POCP))*	[kg C_2H_4 equiv]	CML 2001

Appendix 2: Materials and substances used in seating.

Table A2-1: Specification of materials

Metals	**Textiles and leather**	**Plastics**
Steel plate (specify quality) Steel spring (specify quality) Aluminium plate Extruded aluminium	Wool Cotton Man-made fibres (specified) Textile blends (specified) Leather (vegetable tanning) Leather (mineral tanning)	Acrylonitrile butadiene styrene Polycarbonate Polyamide Polymethyl methacrylate ABS Plastic Polyacetal Polystyrene TPD HD polyethylene (HDPE) LD polyethylene (LDPE) Polyurethane (PU) (foam) Latex Polypropylene PVC
Coating	**Wood**	**Packing materials and other materials**
Lacquer Powder paint Wet painting	Beech Pine Spruce Fibreboard Laminated wood Tropical timber	Cardboard Paper Expanded polystyrene (EPS) Plastic Adhesives

Appendix 3: Examples of calculation of health and environmental impacts.

1) PRODUCTION PHASE

The health impacts shall be calculated according to Table A3-1.

Table A3-1: Health impact classes

Classification	Impacts	Weight(kg) pr Functional unit
Class 1	CMR substances.	
Class 2	Chemicals that: are very toxic, CMR substances group 3, may sensitise by inhalation, danger of very serious irreversible effects or damage breastfeeding children	
Class 3	Chemicals that: are toxic, may sensitise by skin contact, very corrosive, danger of serious damage to health by prolonged exposure.	
Class 4	Harmful, corrosive, danger of cumulative effects, may cause lung damage if swallowed, vapour may cause drowsiness and dizziness.	
Class 5	Irritants	
Class 6	No classified due to health effects	
Total		

The environmental impacts shall be calculated according to Table A3-2.
Table A3-2: Environmental impact classification

Classification	Impacts	Weight(kg) pr Functional unit
Class 1	PBT/vPvB.	
Class 2	Very toxic and may cause long term adverse effects	
Class 3	Toxic and may cause long term adverse effects	
Class 4	Harmful and may cause long term adverse effects	
Class 5	Toxic or may cause long term adverse effects	
Class 6	No classified due to environmental effects	
Total		

2) USE PHASE

Indoor environmental impacts can be calculated according to one or more impact categories defined by the type 1 environment label.

- Indoor environment impacts.

Based on the recommendation in the PCR for furniture, the indoor environment information for furniture could be based on different schemes. The most relevant was pointed out to be

- M1
- AgBB

- Blue Angel
- Greenguard
- Health impact categories according to the DATSUPI scheme

The case material (a seating solution) is tested according to these five methods and the results are presented in this paper for all five methods/schemes in order to evaluate the methods for use in the EPD-context.

Results based on M1 – Emission classification of building materials

Criteria	Test after 28 days
TVOC	xx µg/m^{2}h
Carcinogenic compounds*	xx µg/m^{2}h
Sensory effect	Dissatisfaction with the odeour is below xx %
Formaldehyde	xx µg/m^{2}h
Ammonia	xx µg/m^{2}h
Casein	xx µg/m^{2}h

* carcinogenic compounds: cat 1 compounds

Results based on the AgBB scheme

Criteria	Test after 3 days	Test after 28 days
TVOC	xx µg/m^3	xx µg/m^3
SVOC	- - - - - - -	xx µg/m^3
Carcinogenic Compounds**	xx µg/m^3	xx µg/m^3
Risk index	- - - - - - -	$R = \sum \frac{C_i}{LCI}$
VOC non assessable via LCI	- - - - - - -	xx µg/m^3

**carcinogenic compounds: the sum of cat 1 and cat 2 compounds

Test results based on the Blue Angel scheme

Criteria	Test after 3 days	Test after 28 days
TVOC	- - - - - -	xx µg/m^3
SVOC	- - - - - -	xx µg/m^3
Sum of formaldehyde + acetaldehyde	- - - - - -	xx µg/m^3
Total of other aldehydes	- - - - - -	xx µg/m^3
Carcinogenic compounds**	xx µg/m^3	- - - - -
Individual carcinogenic compounds***	- - - - - -	xx µg/m^3
Risk index	- - - - - -	$R = \sum \frac{C_i}{LCI}$
Not identified VOC	- - - - - -	xx µg/m^3

**carcinogenic compounds: the sum of cat 1 and cat 2 compounds
*** the concentration of each individual cat 1 and cat 2 compound

Results based on the Greenguard scheme

Criteria	Test after 7 days
Individual VOC	$\underline{C_i}$ /TLV_i
Formaldehyde	xx ppm
4-phenylcyclohexene	xx µg/m^3
TVOC	xx µg/m^3
Total aldehydes	xx ppm

Healt impacts (based on the DATSUPI scheme)

Indicator	Unit	Test af 3 days	Test after 7 days
Indoor Air Quality potential[1]	µg/m³		X
Carcinogenic potential[2]	µg/m³	X	X
Teratogenic and/or mutagenic potential[3]	µg/m³	X	X
Allergenic potential[4]	µg/m³		

1: sum of TVOC and Aldehydes
2: sum of compounds classified as carcinogenic in cat 1, cat 2 or cat3
3: sum of compounds classified as mutagenic or Teratogenic in cat 1, cat 2 or cat 3
4: sum of compounds classified as allergenic with risk phrase R42 and/or R43
5: risk index according to the AgBB method or the Greenguard method