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53

Sanna Poikkimäki

Look Closer to See Further

Exploring Environmental Life Cycle Management, LCM

JYVÄSKYLÄN YLIOPISTO

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UNIVERSITY OF JYVÄSKYLÄ

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ABSTRACT

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Companies face increasing legislative pressures to consider the environmental impacts of their products. The product life cycle perspective can also provide opportunities for business development. Product life cycle management, LCM, is an emerging concept describing the efforts to study and develop the environmental efficiency of product life cycles. Its definitions vary and the understanding on its goal and related activities also affect the possible outcomes. The purpose of this study is to explore what is LCM and what are the related activities. The research related to corporate environmental management often relies on realist assumptions and technology-based views. These often fail to grasp the factors related to social interaction, subjective experiences and understanding that may be crucial in advancing environmental considerations in companies, and therefore a phenomenological approach is chosen for this study. An explorative research strategy is chosen to enable the use of different methods and to find authentically new information on the phenomenon. The study consists of two parts. First, the focus is on the definitions of LCM. Interpretative concept research suggests that the three core activities of LCM are (1) producing and using environment-related information, (2) implementing environmental improvements and (3) interaction and co-operation. The suggested environmental improvements by LCM can be seen as innovations. LCM and innovation activities are thus closely connected. Second, the study explores experiences from a case project. Qualitative data from interviews, participant observation and documentation describes a project studying and developing the environmental efficiency of Finnish beverage packaging, in 2000-2002. The case project was considered beneficial due to learning experiences. Data-driven findings suggest that the interaction and co-operation of actors and companies in the case project enabled and enhanced collective, continuous and experiential learning and knowledge creation. Interaction and co-operation were significant since they contributed to the building of professional expertise, to overcoming barriers and motivating for environmental work, to enhancing innovativeness and to implementing environmental improvements. There were also indications of affecting organizational cultures. LCM, when creating detailed environmental knowledge on product life cycles, can thus contribute to the development of dynamic and interactive corporate environmental management, as well as to the related strategic thinking in companies.

Keywords: corporate environmental management, environmental life cycle management LCM, life cycle assessment of products LCA, environmental efficiency, environmental improvement, environmental innovation, interaction, co-operation, knowledge creation

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Kiitos Äidille, Isälle, Mikolle, Jaakolle, Petrukselle ja Kirsikalle, rakastan teitä. ♥
Lämpöiset kiitokset myös appivanhemmilleni.

My father told me that when I was five years old, I did not want to wake up too early in the morning. I had said that when I grow up, I would never go to work. He had asked me what I will do then, and I had replied that I want to ride horses and sing beautiful songs. At some point during my research I realized that this was a very good plan, indeed. And that I am actually not very far from realizing my childhood dream.
So, for me, this is one of those songs.

To all of you that have been a part of it, Thank You!

Jyväskylä, May 2006

Sanna Poikkimäki

Finding the world in the smallness of a grain of sand
And holding infinities in the palm of your hand
And Heaven's realms in the seedlings of this tiny flower
And eternities in the space of a single hour
Send your love into the future
Send your love into the distant dawn

-Sting-

ABBREVIATIONS

AFF	Alternative Function Fulfilment
DfE	Design for Environment
e.g	exempli gratia (for example)
i.e	id est (that is)
IE	Industrial ecology
IPP	IPP, Integrated Product Policy. A Statement by the European Consultative Forum on the Environment and Sustainable Development. (IPP 2001)
ISO	International Organization for Standardization
LCA	Environmental Life Cycle Assessment of products
LCM	Environmental Life Cycle Management of products
PSS	Sustainable product-service systems
SETAC	The Society of Environmental Toxicology and Chemistry
UNEP	United Nations Environment Programme
WBCSD	World Business Council for Sustainable Development
WEEE	Directive of the European Parliament and of the Council on waste electrical and electronic equipment. (EC WEEE 2003)

CONTENTS

1 INTRODUCTION

Due to the legislative and societal pressures, as well as the dynamic nature of production systems, the consideration of environmental issues in product life cycles is currently a topical task and a considerable challenge for many companies. The environmental life cycle management of products, LCM, is an emerging approach responding to these challenges. LCM has been stated to include anything from an entirely new management paradigm (Weidema 2001) to a practical toolbox (Christiansen, in Hunkeler et al. 2001) and everything from concepts to techniques and practical procedures (Saur et al. 2003).(See also Jensen & Remmen 2004.) In order to increase the consideration of environmental issues along product life cycles and assist the development of more sustainable products and production systems, LCM thus needs to be elaborated and exemplified. This research therefore explores the LCM concept and related practical activities in order to discover what it is, in fact, and what are the related activities like.

The needs for a product life cycle perspective in business development stem from the overall goal of sustainability, demands for environmental responsibility and pressures to consider the product life cycle perspective. While societies strive towards sustainability, there are also increasing pressures for companies to carry environmental responsibility.

Sustainability has been defined as "development, which 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). Sustainability is an idea representing overall directions for societal development, and interpretations of its significance and realizations vary. The wide variety of contents and objectives given to sustainability has been predicted to cause controversy, but it has also been stated, that it indicates the emergence of a potentially big idea of general usefulness in the renewal of economies. (Costanza 1992, Costanza & Daly 1992, Daly & Cobb 1989, Gladwin et al. 1995.)

It is commonly agreed that the environmental challenges that societies and businesses face are not disappearing or decreasing (see e.g. Arrow et al. 1995, Daly & Cobb 1989, Hawken 1996, UNEP 2005). Therefore also businesses are

nowadays seen to have an active role in generating essential developments towards sustainability (see e.g. WBCSD 2005, World Economic Forum 2003). However, it is yet to be seen, if it is possible to transform current economic systems into sustainable economies, and what type of change processes are needed to pursue that development (see e.g. Schmidt-Bleek 2000, Shrivastava 1995a, Shrivastava 1995b).

In the business context of individual companies or production chains, the three dimensions given to the sustainability are economic, social and environmental sustainability (Elkington 1997). There are pressures for increasing the social responsibility of businesses and the overall accountability by voluntary schemes and also through legislative demands (see e.g. Elkington 1997, IPP 2001, EC WEEE 2003, EC 2000, EC 2004). However, there are no overall guidelines on how to negotiate or balance the possible trade-off situations between the three dimensions of sustainability. Also, there are often no general consensus or specific ideas on what amount or level of resource consumption, for example, is sustainable or desirable. These questions reflect societal value conflicts connected to the development of sustainability, for which there are no easy or uniform answers (see Goulet 1996). Therefore, the concept of sustainability gives only a general direction for developments and drawing interpretations and practical activities are challenging tasks for companies.

The environmental responsibility of companies is nowadays seen to include not only what happens on their own production sites, but also what happens in the life of their products (see e.g. Klinkers et al. 1999, IPP 2001). Environmental management measures have constantly shifted from the decrease of emissions and waste, the so-called end-of-pipe questions, towards preventive and proactive measures (see e.g. Linnanen 1998). Therefore, attention is increasingly placed on consumption and consumption patterns as drivers for environmental impacts. (Heiskanen et al. 1995, Heiskanen 2004, Welford 2002). It has even been argued, that sustainability goals cannot be met without focus on consumption patterns and lifestyles (Rennings 2000). This places the focus on products as units of consumption. Several new directives also emphasize the product life cycle perspective (e.g. EC 2000, EC 2004, IPP 2001, EC WEEE 2003).

The product life cycle perspective is challenging for management activities, since in many cases it covers a wide variety of companies and actors, as well as processes operated by consumers. Meanwhile, the production networks are more fragmented, international and dynamic and managing development processes is increasingly difficult. As Welford (1998) notes, current social and economic structures are fragmenting into diverse networks often held together by information technology, flexibility and new modes of organization.

The personal interest behind this research stems from a realization connected to such efforts, namely that no matter how valid and reliable, increased environmental information does not necessarily lead to

environmental improvements. My experiences from practical projects have led me to believe that the development of industrial processes and products is not only affected by rational justifications, such as the decreased costs or improved image that are often brought by environmental improvements, for instance. Also, it is not dependent on the existence and price of the technological solutions available. Some more intangible factors promote or hinder environmentally favourable developments. These, I have learned, are connected to the way people perceive, understand and value things, as well as to the ways they interact among each other. There are not, however, many descriptions of these factors and their significance in the environmental management literature.

Within the field of environmental management, development needs connected to the LCM approach can thus be identified. First, the development of LCM has been closely connected to the method of environmental life cycle assessment of products, LCA, which has affected its development. Second, corporate environmental management is a relatively new field of research, where the focus is often laid on quantitative studies and technological solutions that need complementing. Third, the importance of social processes and also inter-organizational co-operation for environmental management has often been emphasized. However, more information is needed on why co-operation is important and how it can advance development. These development needs explain and justify the focus and approach chosen for this research and they are discussed in the following.

From LCA to LCM: an interpretative approach

Behind the development of the LCM concept and methodology, there is a strong tradition of quantitative studies. The development of the LCM concept is closely connected to the method of environmental life cycle assessment of products, LCA.

LCA consists of procedures that aim to compile the flows of materials and energy during the entire life cycle of a product and describe their potential environmental impacts. However, the standardized LCA method focuses on quantitative calculation procedures and includes very little information on the organization and management of the related issues. (see ISO 14040.) Therefore, the organizations of LCA studies and especially the related development efforts have varied. (Frankl & Rubik 2000, Rex & Baumann 2004, Rex & Baumann 2005.) For instance, studies by Rex and Baumann (2004, 2005) demonstrate that there can be considerable differences in the LCA practices of companies. These originate at the differences in the mental approach to LCA activities and also at the related corporate discourses.

Among other reasons, due to the lack of adequate qualitative descriptions or instructions of the development efforts, LCA practices have suffered from problems in complexity of procedures or results, high costs and lack of practical or economic applications. (Heiskanen et al. 1995, Heiskanen et al. 2004, Loikkanen et al. 1999, Frankl & Rubik 2000.) However, the detailed, validated information produced by LCAs is a good basis for environment-related

decision-making. Therefore, more understanding on the related practices is needed in order to proceed from life cycle assessment to actual life cycle management. Findings from previous research suggest that more interpretative understanding is needed on how actors perceive the environment-related research and development efforts and how this affects the practices (see Rex & Baumann 2005) and in what way the companies can benefit from this environmental work (Rex & Baumann 2004).

Also within the field of environmental management on a more general level, needs for complementary, interpretative approaches have been implied. There has been a strong focus on quantitative studies and also on technological solutions for the faced environmental challenges. A need for transformations of management theory and research in support of sustainable development has been stated by Gladwin and his colleagues (Gladwin et al. 1995). Also, Welford (1998) has argued that a post-modernist approach to environmentalism would involve a break with business-as-usual patterns.

Although many environmental improvements are, in fact, somehow connected to technological changes, also more understanding on the perception and interaction of people is needed. The world of technologies and material and energy flows causing environmental impacts is, however, very much related to and affected by individual perceptions and the social world. As argued by Rikhardsson and Welford (1997), it is too stringent an assumption that the four research paradigms, as often referred to after Burrel and Morgan (1989), must be mutually exclusive. The research interests in environmental management thus should not restrain strictly to one research paradigm. Therefore, in order to promote the development of sustainable solutions, bridging between the two is needed.

Although the focus of this research is on issues that are also related to technological changes, an interpretative perspective on the phenomenon of LCM is taken. It provides further enlightment on the contents of LCM by studying the presented definitions and interpretations of the concept. It also studies the experiences of participants of an LCM project and the perceived benefits, thus complementing the current environmental management research with an interpretative and qualitative perspective.

The connection of LCM and innovation: an exploration of concepts

The challenges to measure, to model and to verify the technical or ecological mechanisms causing environmental impacts have been considerable and as Rickhardsson and Welford (1997) state, the views concentrating on technology and eco-efficiency have been dominating the development. Welford (1998) refers to the "technological-fix school of thought" in environmental management. As can be observed in the experiences from LCAs, direct a cause and effect relationship between producing environmental information and implementing improvements has been assumed. An interpretative approach has been suggested to support the research on LCA practices.

Despite of the implied strong connections between environmental management and innovation activities, the understanding on the relationship remains vague in many cases. It is often not defined or described in detail. Also, needs for more systemic approaches and strategies to environmental innovation have been identified, including new models to integrate information and expertise from different sources among companies and industries (Freeman 1996, Brooks 1996). Whether it is believed that technological development can be an overall solution to developing sustainability or not, the connections between environmental development activities and innovations need to be explored and described in more detail.

From the innovation perspective, there are several things that need further elaboration concerning LCM practices. First, more information is needed on what is actually targeted by LCM activities, i.e. what the goal is, and what the related activities are. The definitions of innovation goals have been found to have a significant impact on the realized innovation processes and outcomes (Verargt 1988). Also, it has been found that problem finding and defining can be significant for the formation of professional expertise in development oriented work (see Eteläpelto 1998). The definition and perception of the goal of LCM therefore also affects the perception of the required activities, e.g. in terms of needed resources for data collection and intra-organisational co-operation.

Due to the quantitative and technology focus, in some cases the qualitative aspects like concept research and definition have not been found central in environmental management. In general, the development of environmental management approaches has also suffered from differences and confusions of terminology and overlapping tools, due to their background in specific professional disciplines. (Baumann & Cowell 1999.) This can also be observed in the variety of definitions for LCM. A focus on concepts and their definition is also significant for the development of environmental management as a field of research. Because scientific knowledge is entirely conceptual, proper concepts are needed for good theory formation and good theory formation also contributes to arriving at proper concepts (Lave & March 1993). This research therefore starts by focusing on the presented definitions of LCM, and the implied goal and activities and aims to elaborate further these concepts.

The significance of interaction and co-operation: a data-driven exploration

The activities related to the development of more sustainable processes and products have often been seen as technological changes and innovations. However, the product life cycle view also emphasizes the interaction and co-operation among individuals and companies. In general, it is clear that environmental issues cannot be treated as internal matters in companies without a probability of ignoring significant business risks or opportunities. Also the opinions of external stakeholders[1] and the development possibilities in

[1] Stakeholders are understood here as "any group or individual who can affect or is affected by the achievement of the organization's objectives" (Freeman 1984).

supply chains need to be considered. (see e.g. Hall 2001 , Handfield et al. 2005, Lehni 2000, De Bakker & Nijhof 2002, Boons & Berends 2001, Gunningham & Sinclair 2002, Green & Hunton-Clarke 2003, James et al. 2002, Juniper & Moore 2002, Pesonen 2001 & 2003, Welford 2002, Young & Kielkiewicz-Young 2001.) The environmental impacts of economic operations thus need to be managed in a wider context than that of one organization, to include the entire production chain or an industrial network around a product life cycle (Pesonen 2003).

In practice, for the management of environmental issues, complex choices and reassertion of values are often faced and trade-offs are needed between the different aspects of sustainability, as well as different types of environmental impact potentials (see e.g. Wackernagel & Rees 1997, Walley & Whitehead 1996). The environmental considerations related to different types of production networks are also case-specific, and no overall tool to solve these questions can be developed. Therefore, the development of interactive and co-operative processes and means of discussing and negotiation with other operators or companies in production networks and with stakeholders can assist development and decision-making processes. However, more descriptions are needed of what these co-operational activities can be like. Also, the possible significance of interaction and co-operation for companies and their environmental management procedures needs to be understood better.

In line with the needs to develop networking for environmental management in general, the problems faced by LCA practices suggest that more interaction and co-operation among companies and actors are needed, e.g. to collect valid data on the potential environmental impacts of product life cycles or to implement improvements. However, not only data on material and energy flows, but also value or preference judgements are required for interpreting the LCA data for decision-making for the management of product life cycles.

With merely focusing on technological changes, it is difficult to perceive the sources for the possible usefulness or significance of interaction and co-operation of actors and companies. Therefore, this research employs data-driven findings in order to authentically expand the current understanding on the significance of the interaction and co-operation activities in LCM. Qualitative data from a case project is explored, to discover explanations for the experienced benefits from the interaction and co-operation in the project.

The research approach

The variety of definitions suggests that LCM can be considered as a concept which has no clear correspondent or existence in the realist world. Its contents are defined by researchers and users of the concept, through social processes. This research participates in the definition by seeking to understand what LCM is. Due to the interpretative approach, the aim of this research is therefore not to assist solving all of the practical problems related to LCM practices or to arrive at a final and exhaustive definition of it. The aim is rather to increase the understanding of the phenomena. The aim is also to find relevant needs for future research on an emerging concept. An explorative research strategy

allows combining different sources of information and research methods, and adjusting the research efforts with the built understanding along the research process. For this purpose, also a process of progressive focusing on issues is used.

First, the focus is on the definitions of LCM, the defined goal and related activities, and also the targeted environmental improvements that are implied. The aim is to find the basic elements of the phenomenon, rather than exhaustively deconstruct and reconstruct all the possible contents. Therefore, the used procedure draws from the idea of an interpretative concept research instead of a concept analysis. The interpretations can then show the way for further exploration, both for the following phases in this research and for others to continue further.

Also LCM activities in practice are explored in a case project. It is discovered that the goals set for the activities differ from the experienced beneficial outcomes.

Therefore, a second, data-driven approach is employed. Findings are sought to explain why the interaction and co-operation were experienced beneficial in the case project. The importance of learning in processes seeking environmental improvements or innovations has been stated by several researchers in the field (see e.g. de Bruijn & Tukker 2002, Halme 2001, Carnegie et al. 2000, Sage 2000, Vickers et al. 1999). Based on the data-driven findings, indications on the role of learning in LCM activities are found. This research then demonstrates that the experienced benefits from LCM activities can be technological changes, but also changes of social processes, as well as changes of understanding.

This research complements the earlier understanding of LCM with an interpretative perspective that has previously been called for, and also demonstrates the usefulness of the perspective. It provides an elaborated description of the goal and core activities of LCM, both based on theory and experiences of activities in practice. It demonstrates that interaction and co-operation enhanced learning in the case project and contributed to the construction of environmental knowledge among the participants. Moreover, it contributed to innovativeness. The results therefore contribute to the development of environmental improvements in product life cycles. Also needs for further study are outlined.

2 RESEARCH DESIGN

2.1 Research philosophy

This research employs a phenomenological approach, since it allows a holistic view on the studied subject and study of complex situations (Remenyi et al. 1998). The phenomenological research tradition does not consider the world to consist of an objective reality, but assumes a subjective consciousness. For the phenomenologist, the world is socially constructed. (Remenyi et al. 1998.)

This thesis is based on the assumption, that all environmental considerations in businesses are defined, justified and executed through interactions of actors and companies and socially constructed meanings. Also life cycle management, its definitions and practices can be understood as socially constructed phenomena that are not necessarily objectively observable and verifiable objects (see Berger & Luckmann 1994, Burr 1995).

Several sociological research traditions, including social constructionist approaches, focus on the role of language and other symbol systems in the construction of social realities (Alasuutari 1989). However, language as such in detail is not the main focus of this research. Since knowledge is constructed and sustained through social processes among actors, social interaction of all kinds is an important focus for research (Burr 1995).

Since the focus is on the phenomenon of LCM, it is approached through the meanings and significance given to it by actors and actions both in a scientific and a business context, aiming at an interpretation of its contents and also a contribution to the current interpretations. The research interest is thus interpretative, as defined by Cuba & Lincoln (1994):

> *"The aim of inquiry is understanding and reconstruction of the constructions that people (including the inquirer) initially hold, aiming toward consensus but still open to new interpretations as information and sophistication improve."*

Burrell & Morgan (1989) define interpretative research as research that seeks to understand the fundamental nature of the social world at the level of subjective

experience. Accordingly, social reality is understood as a network of assumptions and intersubjectively shared meanings. The meanings are individual, and can therefore not be true, false, or fully logical (Tamminen 1993). The same is assumed to apply for the definitions and understanding of the goal and activities of LCM.

However, the definitions and practices defined as LCM are seen to aim at objectively observable and verifiable changes in the flows of materials and energy that affect their possible impacts in ecological environments. Thus, through the assumption of the outcomes of these changes being objectively observable, the assumptions about the nature of reality under investigation also include connections to realist considerations and research tradition (see Burrell & Morgan 1989, Remenyi et al. 1998).

The researcher finds that in order to provide a contribution in the field of corporate environmental management, a bridging is needed between the more realist-oriented views of material flow management, environmental improvement and innovation and views considering subjective and social realities. Therefore the research is situated in-between pure constructionist or realist notions. This motivation rises from the field of environmental management research, as discussed in chapter 1.

Also in current sociological thinking the borderline between critical realism and moderate social constructionism as research paradigms has often been thin or even artificial (Suoranta 1997). Arguments have also been presented, that there are more problematic differences between radical and moderate constructionist thinking than between moderate constructionist and critical realist ideas (Delanty 1997).

Although social constructionism is identified as the most significant influence on the chosen perspective, it is not accredited an overall applicability within corporate environmental management. It is here justified and employed as an approach extending the technology-oriented focus of environmental management towards the study of social phenomena and the understanding on the phenomenon as presented in the definitions of the concept of LCM, in other documents or the experiences of actors. Heiskanen (2000a.) states, that although our perceptions of the natural world are socially constructed, an assumption that the social order would precede and influence all our perceptions and dealings with the natural world is problematic for environmental management. The problem is that it would render the natural environment mute and helpless and incapable of influencing us. Complementary perspectives are therefore needed for issues related to corporate environmental management.

Rikhardsson and Welford (1997) argue that it is too stringent an assumption that the four research paradigms, as often referred to after Burrel and Morgan (1989), must be mutually exclusive. Considering that paradigms are ultimately also social constructions and sets of basic beliefs, they can not be proven or validated true, right, or false as such (Cuba & Lincoln 1994). Therefore, this thesis aims rather to find an internally coherent approach, and justify the approaches used based on the set research tasks and a genuine interest towards the subject

and knowledge emerging in the research process, rather than the philosophical or theoretical differences of the paradigms in question.

As in most research settings, underlying normative statements are included in the choice of subject, according a relevance to it (Eskola & Suoranta 1998). Firstly, this research includes an inherent assumption, that taking into account environmental considerations in business development is significant and that the studied issues and questions bear some relevance in the business context. Secondly, based on current societal, political and economic developments, the needs for more environmental consideration in planning and operating product life cycles are seen generally acknowledged and shared among many industries (see e.g. Jensen & Remmen 2004, Krause & Seliger 1997, Seliger et al. 1997).

2.2 Research questions, research strategy and methods

LCM is an emerging concept and its contents have not yet been institutionalized. Also its practical realizations vary greatly. An explorative research strategy is used, since it allows combining different sources of information and research methods, and also adjusting research efforts with the built understanding along the research process (Remenyi et al. 1998). An explorative strategy supports the research process here, aiming at a hermeneutic process, where a deeper understanding is sought through iterations between different sources of theory and qualitative observations (Haaparanta & Niiniluoto 1995, Tamminen 1993, Grönfors 2001).

This research aims to explore the overall theme of what is environmental life cycle management of products and what are the related activities?

Two phases can be identified in the exploration, as presented in figure 1.

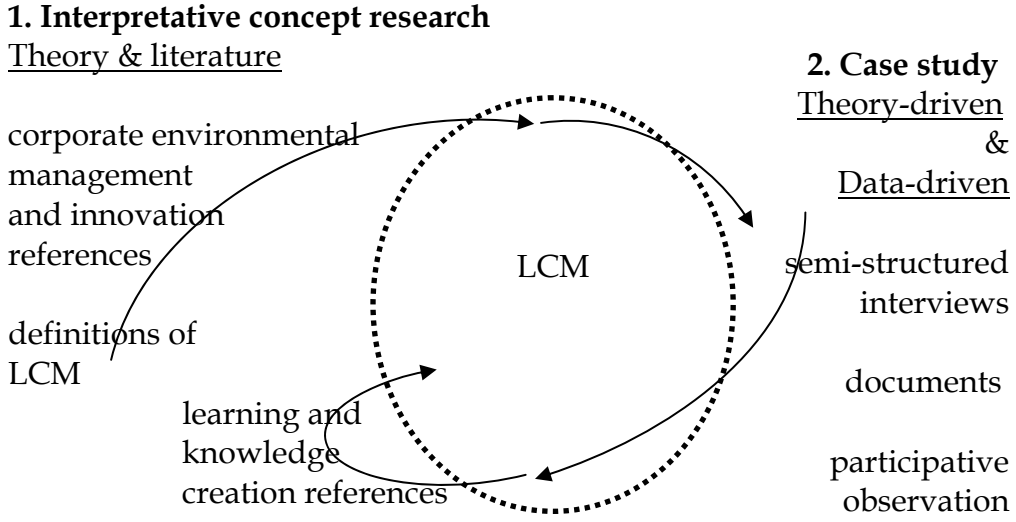


FIGURE 1 Two directions of exploration and sources of data

The first part of the research focuses on the concept of LCM, and its definitions. As outlined in chapter 1, the understanding of the goal and related activities can be assumed important for the practical applications and outcomes from the LCM approach. The first research question is therefore:

1. What are defined as the goal(s) and the related activities of LCM?

Concepts that are accurately and specifically defined are usually most useful, and therefore concept research often aims to find and clarify concepts, that act as tools for thinking. The research follows the idea of interpretative concept research, as outlined by Takala and Lämsä (2001).

The research aims at an understanding of the concept of LCM, its goal and the related activities. The first part employs literature as qualitative data, namely the definitions of LCM in the related definition reports and articles. Therefore, there is and was no direct interaction between the producers of the literature and the researcher. The researcher, however, has an active role in forming an interpretation and an understanding based on this qualitative literature data.

The presented definitions of LCM are seen as individual interpretations that serve the common definition process of the concept. The content can also be other than the explicitly and consciously given one, such as possible background assumptions. Therefore the role of interpretation is seen to be more significant than that of employing certain, detailed and prescribed analysis procedures. Hence, the procedures used differ from the once used for concept analysis. (Takala & Lämsä 2001, Näsi 1980.) The method is based rather on a hermeneutical process of dialogue between theory and data, rather than a systematic process of breaking the contents into smaller units and analysing those contents (Takala & Lämsä 2001).

The aim of the first part of this research is to reach an overall understanding of LCM, instead of an exhaustive, detailed definition. The aim is therefore not to analyse all aspects of LCM and all the related concepts, nor to find an exhaustive definition for the concept. The aim is thus not either to fully deconstruct and/or reconstruct all of the possible contents given to LCM. Due to the many confusions of concept definition in the field of environmental management, as stated in chapter 1, this would be an extensive task and with not much practical relevance. Therefore, this research rather makes an effort to produce an overall view on the elements of the phenomenon and elaborate further some of these. The purpose of this elaboration is then also to indicate further development needs both for the next phases in this research, as well as for other, consequent research.

In concept research, reference information to other, new information structures can be useful (Tamminen 1993). The definitions of LCM are also discussed in the light of a conceptualization of corporate environmental management, in order to discover the basic similarities and differences of these approaches.

Based on the definitions of LCM, three core activities of LCM are identified: (1) producing and using environment-related information, (2) implementing environmental improvements and (3) interaction and co-operation. A further elaboration of the targeted environmental improvements is then expected to provide indications on the other two related activities. The following research question is therefore:

2. What are the environmental improvements in LCM like?

Further references are sought to elaborate on the environmental improvements mentioned in the LCM definitions. The definitions of system boundaries from LCAs and definitions of innovations are used as references, as well as some definitions of the mentioned improvements in environmental management literature.

To proceed, insights from an LCM case project are also sought on the goal and activities of LCM. Case studies have been considered suitable for the realization of an exploratory research strategy (Remenyi et al. 1998). The related research question is:

3. How were the goals defined and how were the most important outcomes perceived in the case project?

It is found that the expected benefits were not always reached in the case project. However, the participants experienced that the process was beneficial. The qualitative data suggests that interaction and co-operation are connected to the experienced benefits. Based on the understanding generated in the first phase of the research, needs to study further the processes of interaction and co-operation among actors and companies in LCM are identified. Interaction and co-operation are, however, estimated complex phenomena and related to many issues relevant for LCM.

Based on the first phase, the second phase then focuses on the interaction and co-operation in a LCM case project. In the second phase, a data-driven approach to the data is used in order to find authentically new understanding on what the significance of interaction and co-operation was in the case project. (see figure 1.) The qualitative data from the case project is acquired mainly by participant observation and semi-structured interviews, of which the methods will be further explained in the following sub-chapters.

The analysis aims at finding reoccurring themes in the data, in order to enlighten the respective research questions. The data-driven analysis is employed here strictly in the context of the defined phenomenon and field of focus. Thus, the aim is not to employ a data-driven analysis to find entirely new theoretical approaches, such as grounded theory (see Strauss & Corbin 1994). The analysis of the case, as of the entire issue, rather aims at progressive focusing, where investigation proceeds through phases of observation, renewed

inquiry and explanation (Stake 1995). Progressive focusing on issues in the research is described in Figure 2.

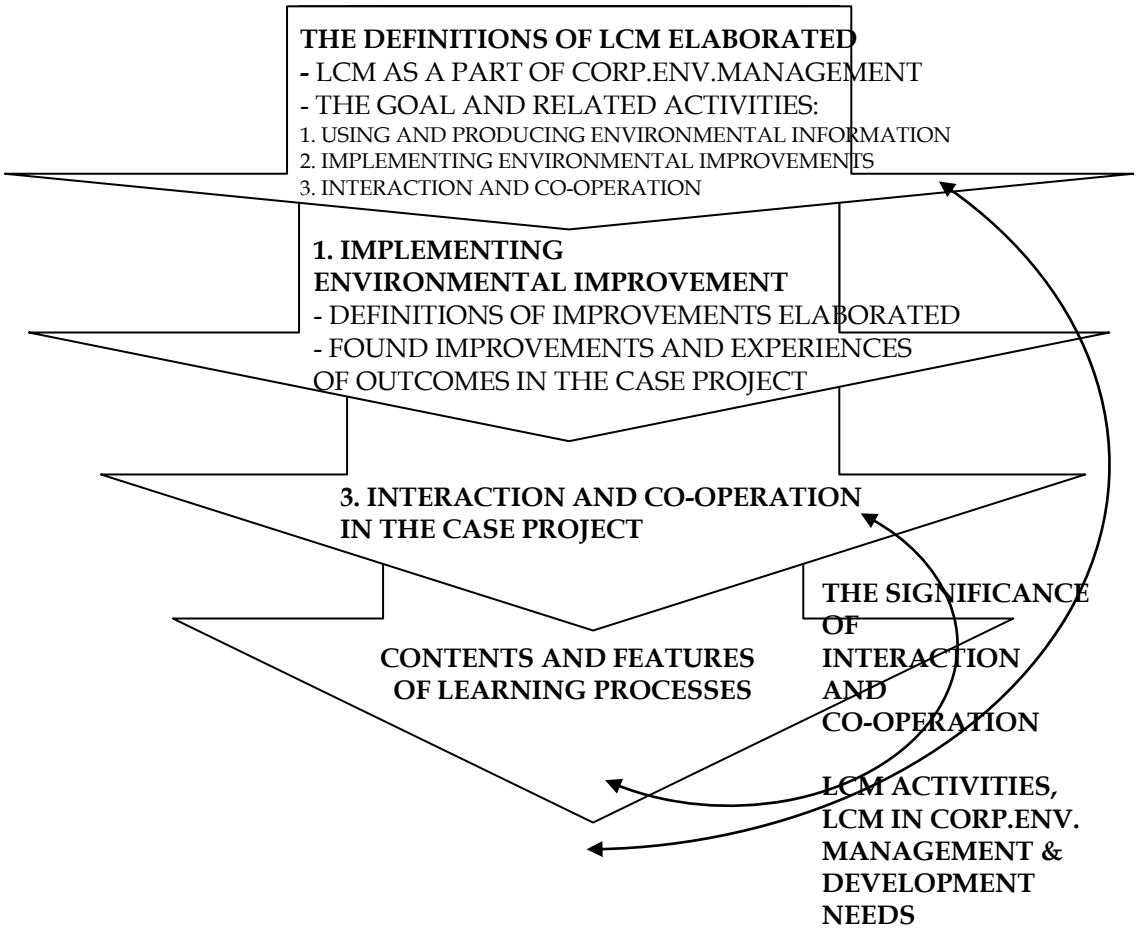


FIGURE 2 Progressive focusing on issues

The data-driven approach was chosen also since it was estimated that it would serve well the study of interaction, co-operation and environmental improvement processes, which are dynamic phenomena by nature. Three more specific justifications were identified. The first motivation was to disrupt from the first part of the study and therefore to serve a genuine exploration and increase the understanding of the phenomenon. The second motivation was to discover indications for other, authentically relevant points of reference in previous literature and previous theory. And third, a motivation was also to discover needs for further research, based on the possible differences or gaps between the current theoretical constructions and the data-driven findings, or the findings in general.

With elaborating reoccurring themes in qualitative data, it is possible to find related topics and affecting variables to a subject. A successful working with themes requires interaction of empirical and theoretical notions. (Eskola & Suoranta 1998.) Themes found in the qualitative data were listed in order to find issues for further analysis and discussion, and it was discovered that the issues are highly intertwined. Many themes, however, were related to learning. The reoccurring themes related to learning and knowledge creation are thus elaborated further by seeking points of reference in previous literature. Based on an initial review of the data, research questions are drawn that deal with the contents and the features of learning processes:

4. What was learned in the case project, related to environmental considerations?

5. What were the learning processes like?

The findings of the contents and the features of the learning processes are then expected to enlighten the initially discovered significance of interaction and co-operation in the case project. The last research question is therefore:

6. What was the significance of interaction and co-operation in the case project?

To conclude the research, interpretations from the case study are discussed. The findings from the concept research and the case study are connected and the implications regarding question 1, on what is LCM and what are the related activities, are discussed.

2.3 The case study

The sources for qualitative data in the field of LCM have not been overwhelming. The approach is new and there have not been many projects, especially in Finland, which would take a product life cycle perspective to produce information and practical improvements of environmental efficiency, with the participation of many different operators. However, it was considered that the project to study the environmental impacts of Finnish beverage packaging done in 2000-2002 included the necessary LCM qualities and it was chosen as a case study (Virtanen et al. 2002, Poikkimäki & Virtanen 2003).

It was stated in the documentation of the project that it aimed to create organisational schemes which will be used for the internal environmental management of the related companies. This was considered as an important new methodological aspect of the project. Also, resources were allocated specifically for the organizational efforts. In practice, there were many processes

related to the actual management of product life cycles, such as building extensive interaction and discussing operative policies among the companies, for instance. These activities were clearly outside of basic LCA tasks, as indicated by the ISO standards (see ISO14040).

The elements of a life cycle perspective, participation of many different companies along the life cycle, aims for producing information as well as practical benefits are important qualities for an LCM project. Also, the time frame covered by the qualitative data collection extended beyond the time frame and the topics of the LCA study, since the interviews were carried out after the LCA process had already ended. These are essential characteristics for the chosen case study since they are expected to enlighten the questions raised in this thesis.

The selection of the case study is thus based on both the characteristics corresponding to the definitions of LCM and on the intensity of available data, meaning that the selected case is rich in information and manifesting the studied phenomenon (see Miles & Huberman 1994). The choice of only one case study is intended to give an in-depth view on the subject phenomenon and support the exploratory nature of the thesis. A sphere of an effort limited in time, space and number of participating operators is intended to allow the forming of a holistic understanding of the process, the interactions and perceptions of participants. A case as an object of study is a phenomenon occurring in a bounded context, and can be an individual, a group of individuals, such as an organisation or a community (Miles & Huberman 1994). In this case, the focus is on the interactions occurring within a temporary organisation of the case project, among a limited number of participants.

It is not self-evident that the knowledge provided by the case study should be generalized to other cases as such. The findings are suspected to be context and case specific. Therefore, the primary aim is to understand the experiences of the participants. However, the data-driven findings are also employed to find indications for further research needs.

It is identified, that there is an underlying normative assumption behind the interpretative approach. Based on the respective development needs in the field, it is assumed that studying these specific topics is important. In addition, the case project is seen as an interesting case as such. Therefore, the research interest in the case study is considered somewhat intrinsic (see Stake 1995), but also instrumental in the sense that the research aims at an increased understanding of LCM in general, and generalizations based on the case findings are not overruled. This corresponds to the phenomenological assumptions related to this research, with strong connections to realist views (see sub-chapter 2.1).

The qualitative data from the case study comes from interviews, participant observation and documentation. Semi-structured interviews were conducted after the project. The interviews are seen as primary data sources. The documentation of the project includes the following documents:

- the research plan
- agendas and memos of the steering group meetings
- agendas and memos of the expert follow-up group
- finalized reports of the case project with attachments

The observations and documentation are seen as secondary sources outlining the context of the case study. Experiential information or direct quotes connected to the interaction and co-operation were rarely included in the official documentation. More enlightening are the personal observations and the notes connected to these documents made by the researcher. In the following chapters, the background of the case project and the data collection procedures for observations and interviews are explained further.

The project to study the potential environmental impacts of Finnish beverage packaging life cycles was accomplished in collaboration with the Industrial Ecology research group of VTT Processes of the Technical Research Centre of Finland as principle investigators, the Association of Packaging Technology and Research PTR as the co-ordinator. Also the three largest Finnish breweries, two largest retail chains and several other companies in the production network of beverages, including many producers of packaging and packaging materials took part in the project. The project lasted from 2000 to 2003.

The work was financed by the Finnish Technology Development Centre TEKES, and companies of trade and industry. Among the financing bodies were also The Federation of the Brewing and Soft Drinks Industries, Finnish Food Marketing Association PTY, beverage logistics operator O-I Finnish Holdings Oy, Environmental Register of Packaging PYR Ltd, recycled plastics operator Suomen Uusiomuovi Oy and alcoholic drinks retailer Alko Oy.

The results of the project and developed procedures were public and aimed to profit also other interested parties than the ones participating the activities or the funding of the project. The main interests involved included the planned changes in the Finnish taxation system for beverage packaging. The results of the LCA study were used for the discussions concerning these changes in taxation. The operators also stated aims to collect exact data, improve the environmental efficiency of their operations in general and answer to legislative or market challenges. The procedures of the project included many forms of dialogue and co-operation among the participants and also other stakeholders to produce and validate reliable and applicable results. (see Virtanen & Poikkimäki 2003, Poikkimäki & Virtanen 2003.) The organisation and process of the case project will be further discussed in chapter 5.

2.4 The role of the researcher as participating observer

Participant-observer research settings carry inherent interpretive philosophical assumptions (Remenyi et al. 1998). For a case study, this signifies that the

researcher aims to clarify descriptions and to elaborate interpretations of the case (Stake 1995). Since researchers are also social actors, conducting research can be seen as a social act. Therefore, to some extent all research on social phenomena is some form of participant observation (Atkinson & Hammersley 1994).

There are many variations to what type of roles the observer can play in the studied situations (Atkinson & Hammersley 1994). In participant observation, the role of the researcher is often in-between active and open participation in situations and passive observer as an outsider (Eskola & Suoranta 1998, Grönfors 2001). Four levels of participant observation have been specified. First, the researcher can be a complete participant, whose research identity is not known by the observed actors. Second, the researcher can be a participant acting as an observer, who is known to be a researcher by the observed. Third, the participation can be only in terms of the research and fourth, the researcher can act only as an observer. (Remenyi et al. 1998, Gold 1958 as cited by Easton 1995.)

In this case, the researcher was an active participant and employee in the case project, but also had an individual research agenda for this thesis. There were clearly defined work-related tasks as an employee, but it was evident that there was also an opportunity to collect observation and other data for further study related to personal research interests. Therefore the roles taken were in-between active and open participation in situations and passive observer as an outsider, as described by Eskola and Suoranta (1998) and Grönfors (2001).

Active and conscious participation of the researcher in the lives of the studied objects is a necessary precondition for participative observation. The researcher aims to be a part of the target group through language and behaviour, and understand the context of events, situations and language. (Tamminen 1993.) As a research method, the participation enables grasping complex processes of social interaction (Easthope 1974). For this research, the active and open participation of the researcher in the case project is seen as a key factor enabling effective participative observation and access to all documentation of the project. In cases, where participating observer enters a cultural sphere not familiar to him or her, culture shocks have been reported (see e.g. Collin 2005). Since the context of environmental management and the used LCA method in the case project were familiar to the researcher, there was no apparent culture shock.

The researcher was part of the scientific team of the case project. The scientific team of five researchers was responsible for outlining the operational procedures as well as co-ordinating the scientific content and results of the study. The participating organisations of the study had several conflicting economic interests, on which the scientific team was not dependent. The researcher and Senior Researcher Yrjö Virtanen were also responsible for the documentation of the process of the project, based on earlier documents and notes on the project as well as interpretation and observations (see Poikkimäki & Virtanen 2003). Thus, the realized organisation and process of the case project were developed in an action research effort (see Alasuutari 1989, Eskola &

Suoranta 1998, Remenyi et al. 1998) between the parties involved in the project and cannot be considered as constructs developed within this thesis. They are regarded as a part of the context of this research.

The participants of the case project were not aware of the details of this research. The ongoing participant observation was also not explicitly mentioned. The research documented within this thesis was thus done as individual work of the researcher. Also, the aim of this thesis is not considered to be the development of a solution for the use of the case project participants specifically, but the development of an interpretation of a more general interest. Therefore, the outcomes of this research cannot be considered as outcomes of action research.

However, the social interaction and discussions with other members of the research team and other participants in the case project have influenced the interpretation of the qualitative data. The understanding formed concerning the case project naturally therefore reflects not only the understanding of the researcher but also some of the opinions and experiences expressed by the other participants of the case project. The interactions gave valuable input in this research process, since some observations and interpretations could be initially evaluated and discussed with the experts participating in the project. These interactions are therefore considered to support the quality of the interpretations. As indicated by Easthope (1974), it has been demonstrated along the development of sociology that interaction benefits participating observation as a research method. Kasanen, Lukka and Siitonen (1991) have also stated, that the overlapping roles of the researcher both as a participant in the studied phenomenon and as an observing scientist are often inevitable in order to ensure the pragmatic relevance of research.

In the beginning, the first observation notes were written merely for fun. Therefore, no clear focus or agenda for the observation was identified. The observation focus developed to be more accurate with time. Making notes was not systematic and they are used only as supporting data for the interviews and documentation. However, the notes are considered as valuable background material and a reminder of events and situations. They were necessary for making the interpretations on the interviews.

Mostly, the notes are observations or direct quotes written on meeting agendas or among other meeting notes in the personal notebook of the researcher. Some observations were also made based on emails and related discussions. Thus, there are mostly three types of notes, as classified according to their contents: observations on LCA procedures, observations on interaction and also some direct quotes of dialogue among the members. All of the notes are in Finnish, except for some notes from the critical panel.

The notes were not specifically organized or numbered for the purposes of this research, but they were marked and left among the original case project files. This way the context of events stayed as intact as possible in the documents. Then the documents were read through iteratively to assist the making of interpretations. Thus they are only here referred to as *Note*s and

numbered in the order in which they appear here, for further reference. For the same reasons that the interviewed actors are kept anonymous, the speakers are not identified in this report (see sub-chapter 2.5).

2.5 Interviews

After the finalization and reporting of the case project, a separate semi-structured interview study was made in 2004. The purpose of the interviews was to study the functionality of the methods and process of the case project for further development of the used methods and processes. A total of 12 operators from two similar projects were interviewed. These projects were the 'Food Chain'- and 'Beverage Packaging' –projects, of which the data concerning the latter is used in this study. (see Katajajuuri 2003, Virtanen et al. 2002.) The focus was on the experiences concerning the process, and the practical actions and future plans connected to environmental efficiency development.

The interviews were used to collect and analyse views of industry and trade representatives on the strengths, weaknesses, opportunities and threats of networked and product-based environmental management. The interview study also aimed at providing data for this thesis, and 8 actors, who had actively taken part in the project chosen as a case study for this research, were interviewed. A semi-structured approach allowed predefined questions that are similar for all respondents, but also an open format for answers (Eskola & Suoranta 1998, Ahonen 1996). In the interview situations, therefore, there were possibilities for further questions and discussion to elaborate on issues experienced significant by the interviewed actors.

The interviewed actors were asked directly about their experiences of the project and its goals, the experienced outcomes, the methods, the organisation and process, gained improvements and benefits. The interviews were personal and lasted approximately 1,5-2,5 hours each, except for one, which was answered by email. The interviews were taped and the answers were typed with slight editing. The used questionnaire is presented in Appendix 1. Most of the interviews were conducted in English, and therefore the quotes appear as they are transcribed from the tapes.

The data with the names of the interviewed operators and the typed answers are kept confidential. It was a set precondition of the study that the answers remain confidential, since it can be crucial for the success of interview practices that the interviewed actors can rely on the confidentiality of the interview data (Hirsjärvi & Hurme 1980). The data also includes some personal notions as well as strategic information for the related companies. Although the perceived conflicts between actors and companies due to personal relations, policy interests or market situations were an important part of the context of the dealt issues, it was an ethical choice of the researcher, that they should not be further enforced by the findings and this report.

2.6 Outline of the study

In chapter 1, the research needs and interests motivating this research are presented. This chapter 2 outlines the research design, philosophical assumptions, research questions, and the used strategy and methods. Also the sources of qualitative data are presented. The theoretical framework of the study will be presented in the next chapter. The chapter 3 outlines the research fields and concepts related to corporate environmental management and to technological development and innovation. With the research fields, also further limitations are drawn to more specifically define the focus of this research and to present the made assumptions. Moreover, concepts are presented to be later used as interpretative references. The conceptualization of environmental management, the definition of system boundaries in LCA, and the definitions of innovation will later be used to elaborate further the contents implied by the definitions of LCM.

Chapter 4 includes the interpretative concept research part of the study. The definitions of LCM and their implications are explored to elaborate on the contents. First, in sub-chapter 4.1.1, the definitions of LCM are compared to the contents of corporate environmental management. In the following sub-chapter 4.1.2, an interpretation is drawn on the main goal of LCM and the related three core activities. These are: producing environment-related information, implementing environmental improvements and interaction and co-operation.

Further exploration then concentrates first on the activity of implementing environmental improvements in product life cycles, in sub-chapter 4.2. The concepts describing the improvements in the definitions of LCM are discussed. Further reference is sought from the concept of system boundary in LCAs and the definitions of innovations that these improvements refer to. Interpretations are drawn on what the implied environmental improvements in LCM can be like. The chapter ends with a discussion of the implications of the concept exploration and indications for further research needs. The findings suggest that the improvements can be defined as product, process and system innovations. The findings of this phase also emphasize the connection of LCM and innovation activities.

Chapter 5 presents the organization and process of the case study in more detail. The process is described through a narrative. Also some examples of the participative observation notes are presented.

The findings from the case study are presented and discussed in chapter 6. The chapter includes exploration from two directions, as outlined previously in Figure 1. The chapter thus begins with an exploration of the goals of the case project in sub-chapter 6.1. The defined goals in the documentation of the project are presented. Some examples of the found environmental improvements are also listed. These two are then discussed with the beneficial outcomes perceived by the interviewed participants.

The findings of the first part of the study suggest that the interaction and co-operation processes need to be studied further. This is the chosen focus for the second phase of the case study, a data-driven exploration of qualitative data from a case study.

In order to carry out a data-driven research process, the qualitative data was approached with an intention to find reoccurring themes related to the processes of interaction and co-operation and their significance in the case project. The themes identified in the data were strongly connected to learning. Thus, the research focused on the contents and process of learning. The learned issues are discussed in sub-chapter 6.2 and the significant features of the learning processes are discussed in sub-chapter 6.3. With the findings, the significance of interaction and co-operation in the case project is then discussed in chapter 6.4.

In chapter 7, the findings from the case study are brought together with the exploration of concepts to draw conclusions. The gained understanding on the significance of interaction and co-operation is combined with the concept research outcome, namely the interpretation of the three core activities of LCM. The gained understanding on the nature of the studied LCM activities is also discussed in the context of the conceptualization of corporate environmental management. In addition, the quality of the research is assessed and further research needs are outlined.

3 THEORETICAL FRAMEWORK

In this chapter, the research fields, main theories and concepts related to the focus and discussed issues are presented. These are related to corporate environmental management, to technological development and innovation. Also further limitations are drawn to more specifically define the focus of this research and to present the made assumptions.

In this chapter, some concepts are also presented to be later used as interpretative references. The conceptualization of corporate environmental management, the definition of system boundaries in LCA, and the definitions of innovation are later used to elaborate further the contents implied by the definitions of LCM, in chapter 4.

3.1 Corporate environmental management and life cycle assessment

The current stream of corporate environmental management is seen to have emerged due to environmental regulations that were introduced in the beginning of the 1970's (see e.g. Walley & Whitehead 1996). The possible relationships between the economic and ecological considerations have been actively debated. Critical perspectives argue that there are no easy solutions to build sustainable worlds. Environmental challenges, especially in the form of regulations and additional costs represent significant threats for businesses (Walley & Whitehead 1996). However, it has also been argued that environmental considerations provide significant opportunities for businesses (Esty & Porter 1998, Porter & Van der Linde 1996).

There are many conceptualizations of environmental management. The conceptualization by Pesonen (2003) is presented, to be used for the discussion on LCM in chapter 4. It will be used due to its clarity and logic. Pesonen (2003) outlines an approach to corporate environmental management with three levels, as described by figure 3. She notes that information about the

environmental impacts of the company and its products forms a basis for all environmental management. Tools to identify environmental impacts include different types of material flow models, like life cycle assessments of products or eco-balances. Knowledge on the impacts also enables companies to actively decrease or prevent the negative impacts, and systematically manage the environmental considerations related to the operations, which forms the second level of corporate environmental management. Management tools include environmental management systems, EMSs, for example. On the third level are possibilities to seek competitiveness through environmental strategies and marketing.

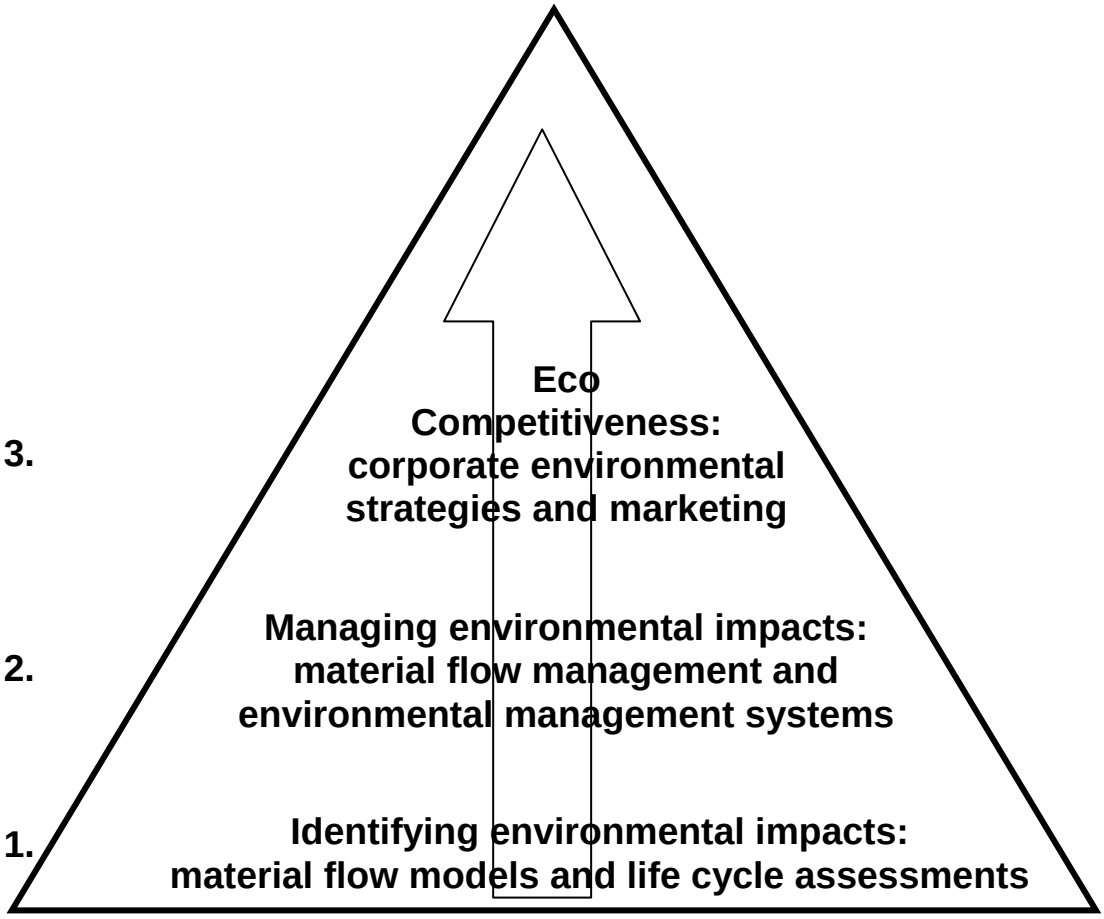


FIGURE 3 Levels of corporate environmental management (Pesonen 2003)

This conceptualization implies that corporate environmental management includes many different types and levels of activities. The conceptualisation also presents an order for consecutive phases. The first level requires a study and research of the flows of materials and energy and the potential environmental impacts of a company and its products. This is seen as a precondition for further study and activity. The managing of environmental impacts can include many different types of activities ranging from operative adjustments to significant changes in processes. A strategic level requires also drawing long-term goals and plans in order to reach changes. On a more

general level, existing relationships between environmental considerations and strategic issues are implied. In general, the conceptualization therefore implies a presence of environmental considerations in strategic decision-making as well as operational processes.

A major influence in the development of the LCM concept can be identified in the development of the life cycle assessment method, LCA. Reasons for this are that LCAs aim to cover the entire life cycle of the product with a level of exactitude that many other methods lack, and that it is a standardized method. Also, some of the experts active in LCA development have also participated in the development of the LCM concept. Therefore, the LCA method and its quantitative focus have also influenced the perspective of LCM considerably.

Studying the environmental impacts of products with LCAs and material flow models has represented considerable challenges for business decision-making. The potential environmental impacts of products and services are formed by complex combinations of flows of materials and energy in the production networks. In the networks, all operations connected to the manufacturing of energy, raw-materials and products, transportations, selling, using and end treatment of wastes have to be included. These are specific to each field of industry, company and technologies used, and their potential impacts are specific to the surrounding ecological environments (see e.g. Klostermann & Tukker 1998, Subhabrata et al. 2003). Many companies do not yet possess comprehensive data on these aspects (De Beaufort et al. 2001, Frankl & Rubik 2000), nor have processes where this understanding could be formed and filtrated further into decision-making and practical operations.

Material flow models are used as tools for identifying the environmental impacts of limited units of operations. They consist of a *system* model with a defined system boundary, *processes* describing transport, transformation and change of value of materials and goods and *flows* describing transport of products, materials or energy between the processes. The system model has defined *imports* and *exports,* and each individual process has defined *inputs* and defined *outputs*. The flows, inputs and outputs can be measured in either goods (materials or material mixtures with economic value) or materials and substances (chemical elements and their compounds). Material flow models are based on two laws of thermodynamics. The first law states the conservation of materials and energy and the second law states that entropy grows in closed systems. (Baccini & Brunner 1991, Pesonen 1999, ISO 14040.)

Studies and models of material and energy flows that use these concepts can be defined as material flow models, including for example LCAs, ecobalances, screening methods and eco-matrixes (see e.g. Pesonen 1999). These methods differ, for instance, in focus and in exactitude. Life cycle assessments focus specifically on assessing reliably the potential environmental impacts of product life cycles.

Life cycle assessment, LCA, is a standardized, quantitative method to study the potential environmental impacts of products during their entire life

cycles from the gradle to the grave (ISO 14040, Weidema 1997). LCA techniques are based on economic input-output analysis introduced by Leontief (1986). It is based on calculations of material and energy flows employing quantitative process data. The calculation focuses on a production network of one specific product or product group fulfilling a specified function, the functional unit of the study. (see ISO 14040.)

An extensive amount of data is needed for an LCA calculation. Also, the procedures are complex and cannot always be performed in a transparent and valid way. (Heiskanen et al. 1995, Loikkanen et al. 1999, SETAC 1992.) The availability and quality of data have been among the most severe problems encountered by LCA efforts (see Braam et al. 2001, De Beaufort et al. 2001, Huijbregts et al. 2001).

LCA has been promoted as an environmentally-oriented decision-making tool, but it can also be seen rather as a method for structuring information and directing attention and action (Welford 1995, Heiskanen 2000a.b., Baumann 1998). Heiskanen (2000a.) defines LCA as a model of human-nature interaction, which is linked to a number of techniques and practices. She also defines life cycle approach as discourses, practices and techniques that relate products to environmental impacts in their physical life cycle. In practice, LCAs have frequently failed to produce conclusive support for decisions, although companies may have spent relatively large amounts of money on LCAs and on finding out about environmental concerns elsewhere in production chains, which they are not legally responsible for (Heiskanen 2000a.).

The relationship between LCA results and decision-making processes is not simple and straightforward, as demonstrated by Baumann (1998) and Rex and Baumann (2004). A study on the use of LCA in Europe also demonstrates that many LCAs lack practical or economic applications in process and product development (Frankl & Rubik 2000). Therefore it can be suspected that LCA activities are disconnected from innovation activities in companies and that they may lack features that enhance innovativeness.

Several essential features for timely, cost-effective and innovative product and process development processes have been identified. Among these, for example, are problem solving methods based on overlapping and cross-functional handling of issues instead of handling within functional groups or disciplines. Consequently, information is transferred in numerous two-way exchanges throughout the development process, instead of downstream transfer of information and reporting the phases after completion. (Hayes et al. 1988.) The lack of practical applications of LCAs in product and process development suggests, that the method has often lacked some of these features and also lacked integration into the innovation functions of the organisations participating LCA efforts. This conclusion is not surprising as such, since the LCA standard does not include many instructions for the organization and process of LCA studies.

3.2 Environmental efficiency and environmental improvement in the business context

The contents given to concepts of environmental efficiency and eco-efficiency are overlapping. However, an interpretation can be made that these also have significant differences. These concepts will be discussed here and the choice of the concepts of environmental efficiency and environmental improvement will be justified for further use in this thesis.

The concept of eco-efficiency differs from environmental efficiency by more direct implying what is its relationship to economic efficiency. As economic efficiency is defined in terms of cash flows causing the economic impacts, environmental efficiency can be defined in terms of material and energy flows causing the potential environmental effects. An important difference of the two types of flows is that the flows of cash can be calculated and represented in comparable units of value. On the contrary, the flows of materials and energy appear in various different qualities with different values. (see e.g. Pesonen 1999.) The flows of materials thus appear in endless combinations of substances, which also have an enormous variety of economic values. This is due to their usefulness in the business context as raw-materials or fuels, or their harmful effects as emissions and wastes. Most of these flows can be valued in terms of cash, but also in terms of ecological or social values, like impact potentials, preferences and acceptability. Therefore, drawing the flows of materials and energy or their potential impacts into comparable units or into cash flows requires value judgements, i.e. valuation (see e.g. Lindfors et al. 1995).

Eco-efficiency is a commonly used term to describe a business perspective to environmental efficiency. Schmidheiny (1992) defines eco-efficiency as "the ratio of resource inputs and waste outputs to final product". Since the concept of product inevitably implies an economic value related to the product, it is also implied that the mentioned ratio of inputs and outputs can be attributed a corresponding economic value.

Schaltegger and Sturm (1992, as cited by Helminen 1998) define ecological efficiency as a desired output per environmental impact added. The term environmental impact added refers to a commonly used measure of adding up the relative environmental impact potentials of a product system into a sum of environmental impact added to the ecological state, i.e. the overall impact caused. (see e.g. Wathern 1990). This definition, however, also includes a reference to traditional economic production efficiency thinking, providing an alternative perspective; it suggests considering the mentioned ecological efficiency of production. The definition therefore also implies that companies can include flows of raw-materials and energy into their follow-up routines, like raw-material efficiencies, emissions and waste. The operational efficiencies are emphasized as aims of efficiency development.

The definition implies that the definition of the desired output would not occur on environmental basis and would be taken as a given unit. Therefore, it

is not implied that the outputs or products should be reconsidered, or could be changed or redesigned in order to improve the ecological efficiency. However, these options are not overruled in the definition, either.

Many definitions of eco-efficiency stress the idea of maximizing product or service value per environmental influence (see Helminen 1998, Lehni 2000, Paloviita 2004). Thus, the goal of eco-efficiency would be to produce maximal value per environmental impacts caused. The term value refers to financial value, but it could also be extended to include other added value to the product, such as information or quality. Also environmental or social qualities of a product could therefore equally be goals of eco-efficiency, in addition to the economic value. Some definitions also relate eco-efficiency and sustainability. WBCSD (1996, as cited by Helminen 1998) defines eco-efficiency as follows:

> *"Eco-efficiency is reached through competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing environmental impacts and resource intensity through the life cycle to a level at least in line with the earth's estimated carrying capacity."*

As a conclusion, there seem to be several components to eco-efficiency. First, there is a goal of environmental efficiency in minimizing the potential environmental impact added. Second, there is a goal of maximizing the economic and other values gained through this efficiency. Third, there is an overall goal of reaching a sustainable level of operations. Thus, from a management perspective, striving for eco-efficiency requires the management of both cash flows and flows of materials and energy - and also knowledge of different aspects of sustainability in a wider context. Eco-efficiency can be thus interpreted to differ from environmental efficiency by including also economic and social considerations.

Various methods of evaluating the economic impacts of changes in business operations have been developed and commonly used in companies. The relationship of environmental and economic impacts of changes is also expected to vary case-specifically. The focus of this research is therefore on the environmental aspects of changes. The methods used for economic evaluations can also differ according to the time perspective of the changes in question and vary from operational accounting to return on investment accounting, for instance. Social sustainability is equally a complex issue with many specific considerations and therefore it is not studied here either.

The flows of materials and energy are seen as portrayals of the potential environmental impacts of operations. Therefore, the concept of environmental efficiency is used in this thesis, although it is recognized, that economic assessments are an inevitable part of all business activity. Consequently, the concept of environmental improvement refers here to a change increasing the environmental efficiency of a process, a production network or any such unit of study. These are then changes that increase the efficiency of materials and energy use, i.e. decrease the total use of resources or decrease the produced total emissions and waste.

3.3 Environmental improvements and system boundary

The life cycle of a product includes a vast production network of all operations throughout the life of a product, from raw-material acquisition to end treatment of wastes. In order to elaborate the definition of environmental improvements from a life cycle perspective, definitions used in the environmental assessment of products, LCA, can be applied. For this purpose, the definition of a system boundary is discussed in relation to the previously discussed concept of environmental improvement. It is argued that all environmental improvements have a system boundary of effect. This definition will be then used in chapter 4 to discuss further the environmental improvements implied by the definitions of LCM and related implications.

According to the definition of environmental efficiency, the material and energy flows of a production network are representations of its environmental efficiency. The potential environmental impacts can then be calculated through the impact potentials caused by the total material and energy inputs and outputs of the network. The definition of the functional unit and system boundaries outline the studied network, which are described by the results (see ISO 14040). The functional unit of a production network is, then, the key function that its operations, products or services are intended to serve. A system boundary defines the extent and quality of the production network included in the study, in time, space and technological level.

The calculation of the total material and energy inputs and outputs is ideally based on the detailed calculation of the respective data on each, individual process in the production network. The environmental efficiency of an individual process can therefore be defined as the quantity and quality of inputs and outputs, e.g. the resources needed or the emissions created per unit of function served, as described in figure 4. Following this definition, the environmental improvements or any changes in the material and energy flows of an individual process or of a network can then be defined as changes in the quantity and quality of the input materials and/or the changes in the quantity and quality of the output materials.

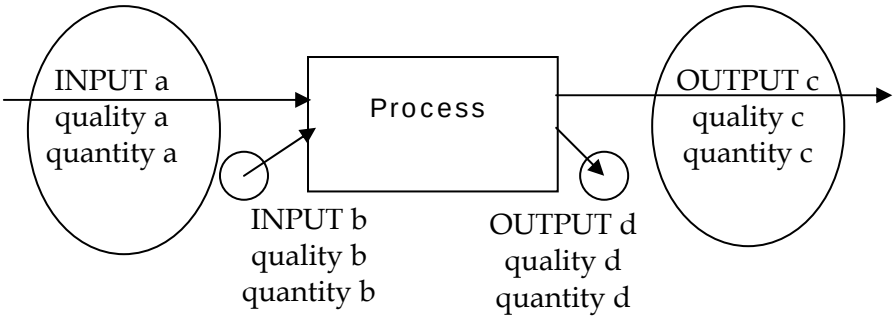


FIGURE 4 Flows defining the environmental efficiency of a process, an example

A change that increases the resource efficiency of the process and the quantity of the valued or intended outputs, and also decreases the quantity of the harmful outputs, for example, is a clear environmental improvement. By changing the outputs of the process, these changes affect the following processes in the production network or in the ecological environment. Therefore, all changes in a process inevitably affect also some following processes. However, in cases where also the inputs are subject to changes, also some of the previous processes in the production networks consequently change. Each change has thus a system boundary of effect, describing how many processes in the chain are affected.

The number of processes affected or changed, however, does not indicate the environmental significance of the change, since both the quantity and quality of the flows are subject to change. From the environmental perspective, a change of flow quality with a smaller system boundary can be more significant that a change of flow quantity with a larger system boundary. Therefore, in environmental evaluation, the environmental impacts of a change of quantity, usually to decrease the flow of a material, are easier to estimate as being environmental improvements than changes of quality.

Since the different qualities of materials also have the potential to cause different types of impacts, assessing preferences among these for decision-making also requires value judgements (see e.g. Wathern 1990). The problems connected to the use of values have been discussed, e.g. in connection to the impact assessment and characterization procedures of LCA (see e.g. Loikkanen et al. 1999).

The definitions of the functional unit and system boundaries are conceptual decisions in the study of environmental impacts of product life cycles, since production systems are stated to be open, interconnected systems interacting with each other, but also with the surrounding ecological systems (Baccini & Brunner 1991) and their all flows cannot be grasped with detailed material flow studies. However, these definitions affect greatly the perception of caused environmental impacts or gained improvements. By defining a system boundary for the changes, it can be noted that most changes have cumulative and indirect effects. Consequently, many organizations in production networks can be touched by the changes, and therefore new perspectives also for the management of changes may be needed, extending the focus beyond organizational borders.

The significant notions introduced by material flow studies and LCA are that when environmental improvements are assessed from the perspective of entire production networks instead of one company or organization, also their cumulative and indirect effects in other processes can be observed. This introduces the life cycle perspective enabling more holistic assessments and management approaches.

3.4 Technological development, innovation and the environment

Technology is defined as "a combination of equipment and knowledge" (UN 1999). New ideas, *inventions* that "are successfully produced, assimilated and exploited of novelty in the economic and social spheres" are defined as *innovations* (EC 1995). Environmental issues are seen to have considerably changed both the conditions under which innovations are produced and disseminated and the underlying reasons for interventions in innovation activities by the authorities (EC 1995).

The discussion of the relationship between technological development and the environment can be characterized by two opposite views. A connection between economic growth and the level of environmental protection has been observed, although it has also been stated that there are no valid evidence that economic growth will be environmentally beneficial (Ayres 1997). Hockerts (2003) states that innovations have been proposed as a source for "environmentally benign growth". He defines *sustainable innovation* as "any process of social change which increases the proceeds derived from current natural, social and economic capital, while at the same time protecting and enhancing the underlying capital stock" (Hockerts 2003). The definition relies on an assumption that sustainable innovation is possible, of which case examples are also demonstrated.

The UN (1999) definition of *environmentally sound technologies* also supports the notion that the co-evolution of sustainability and technology is possible. Environmentally sound technologies are defined as "techniques and technologies capable of reducing environmental damage through processes and materials that generate fewer potentially damaging substances, recover such substances from emissions prior to discharge, or utilize and recycle production residues. The assessment of these technologies should account for their interaction with the socio-economic and cultural conditions under which they are implemented."

According to more critical views economic growth is not an assurance for environmental quality, but what matters is the content of growth (Arrow et al. 1995) or the limits set to it by the ecological environment (Meadows et al. 1997). Also, the effects of technological improvements are constantly eaten away by the growing volumes of consumption, production and waste generation. Wackernagel and Rees (1997) argue that the individual effective and efficient performances of technological developments enhance the positivist belief that technology can solve the limits set by the ecological environment and that sustainable growth is possible, also even though technological solutions would be sought only after the problems arise. Therefore, they are sceptical about the capabilities of technological developments in building sustainable societies. Welford (1998) is also critical towards the abilities of technological development alone in solving sustainability problems. Arguing against the possibility of continual growth, he states, that the concepts and models of eco-efficiency are

often closely linked to the "technological-fix school of thought", where technology and science are seen essential in solving sustainability problems, and traditional capitalism and economic growth is supported against the ecological restraints.

The conclusions on the environmental impacts of technological developments depend highly upon the perspectives and context in which the question is studied, and what data, evidence or understanding the arguments are based on. For many businesses or industrial sectors, there are no guidelines available describing the sustainable level of resource consumption or impact potentials. Therefore, it is often impossible to evaluate the possibilities of current or future companies, production systems or societies to reach a sustainable level in practice. It is also difficult to evaluate the role of technological developments in aiming for sustainability in the future, since there is little valid information available on societal developments, future regulation, infrastructures, consumer values and other incentives, or technical possibilities. The lack of valid scientific evidence on the right solutions, however, can not be an argument for disregarding environmental considerations. There is already plenty of evidence of global ecological problems and also experiences of problems. Therefore it is necessary that all societal operators take part in developing the solutions, including business actors. (Rikhardsson & Welford 1997.)

This research does not aim to support the notion, that technological developments would as such provide the needed solutions to environmental challenges. The aim is rather to interpret some pieces of relevant information that may support the development of sustainability of businesses. Clearly, technological change is seen as one useful perspective in responding to environmental challenges by businesses, while also acknowledging the critiques that it should not be the only approach considered. Therefore, the potential of technological changes to solve environmental questions on the level of economies, production networks or individual companies are not discussed further in this research.

Depending on the perspective, the innovation framework is either formed on a macro-level or on a micro-level. A macro-level perspective describes how an innovation is new to the world, the market or an industry. A micro-level perspective rather describes how the innovation is new to the firm or the customer. This division is also connected to a notion to separate the general innovativeness within companies and the innovation environment in-between companies (Garcia & Calantone 2002). The life cycle perspective includes micro- and macro-level considerations, and moreover, also considerations of connections between these levels. Thus, it is related to innovativeness both within and in-between companies. Accordingly, this research takes the perspective of one company and of a group of companies interacting and co-operating in a product life cycle. Therefore, the focus is on the activities within a company and among a group of companies.

Van de Ven and Poole (1990) outline five sensitizing categories for the study of innovation development: ideas, people, transactions, context, and outcomes. The process of innovation consists of motivating and coordinating people to develop and implement new ideas by engaging in transactions with others and making the adaptations needed to achieve desired outcomes, with changing institutional and organisational contexts. Van de Ven and Poole (1990) state, however, that even though many simplistic assumptions have been made in previous innovation literature, field research has enabled more versatile views of these categories.

The main focus of this research is on the understanding of the LCM and related activities. Due to the chosen focus, the innovation context of each individual company can not be discussed in extensive detail. It is acknowledged, however, that the individual motivations, the market situations and policy pressures affect the companies within the studied network, although they are not within the studied focus and cannot be discussed in detail.

For this research, the goals of innovation are both ideas and realized innovations of environmental improvements. There are two justifications for not separating the ideas and actual innovation outcomes further.

First, the processes and factors affecting the establishment of ideas as innovation outcomes in business operations are complex. According to Van de Ven and Poole (1990), field research has demonstrated that innovations are not generated in simple processes, with cumulative sequences of stages or processes. De Bruijn and Tukker (2002) also note that innovations do not always evolve through similar phases or routes. The processes are rather multiple progressions of divergent, parallel and convergent paths, some of which are related and others are not.

Due to the complexity of innovation processes, it cannot be assumed either, that the best inventions should always be developed into successful innovations. As stated by Van de Ven and Poole (1990), innovations are often not based on a single idea, but there is rather a process of reinvention, proliferation, reimplementation, and also of discarding and termination of ideas. The people concerned with innovations are not necessarily entrepreneurs with fixed sets of full-time people. They are rather a group of many actors, distracted, fluidly engaging and disengaging in a variety of organisational roles. Their transactions are not seen as fixed networks of people or firms working on ideas, but rather expanding and contracting networks of partisan stakeholders diverging and converging on ideas. The outcomes of innovation are not necessarily stable new orders that come into being, but indeterminate, multiple in-process assessments and spin-offs, that integrate new orders with old ones. (Van de Ven & Poole 1990.)

Second, these complex innovation processes can also be assumed time consuming endeavours. An initial screening of the qualitative data from the case project indicates that some improvement ideas generated in the case project are only starting to enter this process during the time of observations or

interviews. They can therefore be established and diffused as innovations later, after the observations and interviews.

Therefore, it is also outlined that this research is not assuming a direct route of development from invention to innovation and through incremental improvements towards breakthroughs. Innovation processes are seen as complex, iterative and uniquely case-specific processes. Due to the chosen focus and research design, the aim is also not to model or describe the phases of the innovation process, but rather to find relevant perspectives that contribute to an understanding of the possible relationship of LCM and innovation processes.

3.4.1 Incremental and radical innovations

Freeman and Perez (1988) formulate a taxonomy of innovations distinguishing incremental innovations, radical innovations, new technology systems and changes of techno-economic paradigms, according to the nature and scope of the effects of innovations.

On the level of individual innovations, the development is thus seen as a succession of technologies replacing older ones and becoming dominant in the market after a period of development, and reaching a certain maturity level. The dominant designs are elaborated with incremental innovations, which imply only moderate changes in production systems. Finally, the dominant designs are replaced by new ones. These technological breakthroughs are defined as more fundamental, radical changes that affect processes or products and develop to dominant designs through an era of ferment. (Tushman & Anderson 1986.)

The technological breakthroughs bring technological discontinuities, which have been further divided into competence-enhancing or competence-destroying discontinuities. A competence-enhancing discontinuity builds on and contributes new features to the existing technical order, bringing new technology systems. A competence-destroying change is defined as one that renders obsolete the expertise required to master the technology that it replaces. (Anderson & Tushman 1990.) Radical, competence-destroying innovations have effects transforming the existing technical order (Tushman & Anderson 1986). Therefore, entire economic systems are changed, i.e. the techno-economic paradigms are altered (Freeman & Perez 1988).

Technologies have also been defined according to their stages of development as mature, incremental and radical technologies (Grübler et al. 1999). Grübler et al. (1999) argue that the costs of technologies are reduced and economic performances are improved through learning. Mature technologies can change or improve under competitive pressure, but in general have stable performance and costs. Incremental technologies are found in niche markets and offer some performance advantages and a potential for significant cost reductions with continued investments. Radical technologies are more uncertain, both in their potential for improvement and in their arrival on commercial markets at all. Also, corresponding to the concept of the techno-economic paradigm, he states that there are regular patterns of dynamic

competition between technologies, a co-evolution of long-lived infrastructures and technological clusters due to ”network effects”. (Grübler et al. 1999.)

Based on the socio-technical change theory, De Bruijn and Tukker (2002) outline a multi-level perspective on innovations with three levels where innovations take place, *the socio-technical landscape, trajectories and niches*. The *socio-technical landscape* level refers to factors that change slowly like material infrastructure, cultures, life-styles, demography and so on. The landscape factors direct *the socio-technological trajectories*, which correspond to the previously defined techno-economic paradigms, i.e. the existing order on the industry-level. However, the concept of socio-technical trajectory extends the view to covering also companies, consumers, policy makers and other stakeholder groups. De Bruijn and Tukker (2002) define all innovations demanding a change in the socio-technical trajectory as *system innovations*, with the important notion that their development is affected by various social constellations (Rotmans et al. 2000, as cited by de Bruijn & Tukker 2002).

Trajectory level innovations, then, are developed in connection to innovations in *niches*, which are innovations in limited areas. De Bruijn and Tukker (2002) define that these are new technologies that are developed under relatively protected circumstances. They also state, that there is not yet extensive research on the process of innovation and the effect of policies, although some tentative ideas have been presented.

Innovations have also been divided into product innovations and process innovations which develop in an interaction with each other (Utterback 1994). This division implies strongly a market-oriented view and a perspective of one company, with emphasis on the diffusion of new products in the market. From the perspective of developing an entire production network, however, the division into process and product innovation from the perspective of one company does not appear so useful, since the products sold by other companies serve the processes of others. For life cycle management purposes, however, it may be more useful to refer to the products of the entire network, which serve a function for the end users and connect together all the operations of the life cycle. With LCA terms, this corresponds to the definition of the functional unit (see ISO 14040). A product innovation in the context of life cycle management can then be defined as an innovation changing the end products or services of the network, i.e. the functional unit of which the life cycle is concerned.

Many experts believe that in any case radical changes of economic systems are needed before a sustainable level of resource consumption and impact potentials can be approached (see e.g. Schmidt-Bleek 2000). However, incremental developments can equally be important from the economic point of view, since there are examples that cumulative gains in efficiency are often more significant over time than the gains of more radical developments (see e.g. Tidd et al. 1997). There is no evidence, that either radical or incremental innovations would be more significant in terms of environmental improvements. Freeman (1996) has stated that in order to approach

sustainability, the need for radical innovations is quite evident in some industrial sectors, but also continuous incremental improvements are needed.

3.4.2 Technological, organisational, institutional, social and environmental innovations

There are several definitions and typologies of innovations, which has also lead to confusions in the field of innovation research (Garcia & Calantone 2002). However, innovation theory is fundamentally a theory of change (Hockerts 2003). Innovations can reach for or result in changes of technological, organizational, institutional, environmental and social processes.

The concept of innovation is most often linked to technological and technical innovations with a certain market potential or market effects as commercial products. However, in addition to being technological, innovations can also be organizational, social and institutional (Rennings 2000). Organizational changes refer to the use of various management instruments and social changes are changes of lifestyles, consumer behaviour and consumption patterns. Institutional innovations are measures such as building local networks, agencies and governance. Rennings (2000) states, that the distinction between different types of innovations cannot be very sharp.

The concept of social innovations refers to changes that enhance social and cultural development, or prevent changes that are considered negative in the society. The generation of social innovations has been stated to depend on societal learning processes that enable structural changes and renewal. Social innovations are therefore mainly connected to public sector activities. However, it has been mentioned, that social innovations are generated by both public and private organizations and co-operative networks, both nationally and internationally. (Hämäläinen & Heiskala 2004.)

The concept of social innovations introduces an important perspective to innovation goals that are not essentially defined by economic success or returns, but on social benefit. Since sustainable development outlines overall directions for societal development that many countries are committed to, improvements to increase social, economic and environmental sustainability can all be seen as valid goals for social innovations. Therefore environmental innovations can also qualify as social innovations.

Hall (2001) defines environmental innovation as a new product, process or technology developed and/or adopted by a firm to reduce environmental impacts. He also defines environmental supply-chain innovations as situations, where a supplier, under the advice, coercion or direction of a customer firm, adopts an environmental innovation. He calls for these interfirm innovations, i.e. an interaction and exchange of information, and possibly also joint action for the development of sustainability.

While the primary definition of success for all business activity and innovation is success in bringing economic returns, an environmental innovation, however, can have a definition of success in bringing environmental improvements and knowledge that enables those improvements.

Rennings (2000) defines eco-innovation as "development, application or introduction of ideas, behaviour, products and processes that contribute to a reduction of environmental burdens or to ecologically defined sustainability targets". According to the definition, environmental innovations can be objects tradable on the markets, i.e. products or other objects with or without market value. However, based on the definition, environmental innovations can be also other changes, such as increased knowledge or changes of social processes bringing forward environmental improvements.

Increasing focus is placed on the social and environmental aspects of innovation. It has been stated that the narrow perspectives and motivation for innovations provided by traditional economic theories have resulted in problems with policies and with economic growth. An ongoing techno-economic paradigm shift has been identified, calling for radical changes in the quality of production inputs, technologies, organizational structures, markets and international business. In the emerging paradigm, the core resources, technologies and organizational innovations are suspected to develop locally, without general standards, and their transfers across national and organizational borders is therefore suspected to be difficult. (Hämäläinen & Heiskala 2004.)

It has been generally acknowledged, that knowledge is becoming a core resource for economic development (OECD 1996). There are also examples of environmental data, successful sustainable innovations and sustainable business strategies developing highly industry- or even case-specifically (see e.g. Baumann 1998, Klostermann & Tukker 1998, Hockerts 2003). The related environmental knowledge can therefore be seen as an example of these new kinds of core resources employed in the emerging economic paradigm. Consequently, also the building and the role of the environmental knowledge are important for future success of innovation activities. These ideas highlight the importance of environmental considerations in the development of products and processes that have already been acknowledged (see Chapter 1.). Thus, it is important to consider the relationship between environmental considerations and innovation activities.

The understanding on innovations and innovativeness will be used to elaborate the understanding on the environmental improvements connected to LCM, and also to discuss the findings related to the interaction and co-operation in the case project. This procedure will further emphasize that LCM activities are related to innovation activities, and also expand the perspective to an increased consideration of social changes, in addition to the technological ones.

4 EXPLORING LCM

In this chapter, the definitions of LCM are discussed and elaborated on. First, the definitions of LCM are presented. The definitions are then discussed with a conceptualization of corporate environmental management, to find out the main similarities or differences of LCM and environmental management.

The chapter proceeds to making an interpretation on what is implied to be the overall goal of LCM and what are the related activities. The definitions of the activities implementing environmental improvements are then elaborated further, by drawing interpretative reference from the concept of system boundary and the definitions of innovation and other, related concepts from environmental management literature.

4.1 The definitions of LCM

A great variety of approaches and tools have been related to LCM. The found definitions of LCM are collected in Table 1. These were found in the definition reports of LCM and articles of corporate environmental management where LCM is conceptualized. The variety of contents can also be seen in the illustration of LCM by Jensen and Remmen (2004), as presented in Figure 5. It seems that LCM can cover any environmental considerations in a company or among several companies along a product life cycle, from an entirely new management paradigm to a certain perspective and to the use of specific tools, such as LCA. The definitions are thus wide and the concept needs further developing.

> *"Life cycle management consists of three parts: (i) integrating environmental issues into the decision-making process of the company; (ii) optimizing the environmental impact caused by the product system during its life cycle; and (iii) creating a new organizational culture to support the decision-making process." (Linnanen et al. 1995)*

> *"LCM assures that the process used across projects are consistent and that there is effective sharing and coordination of resources, information and technologies. This Life Cycle spans the*

conception of ideas through to the retirement of a system. It provides the processes for acquiring and supplying system products and services that are configured from one or more of the following types of system component: hardware, software and humans. In addition, this framework provides for the assessment and improvement of the Life Cycle." (ISO/IEC 15288 DC2 2000.)

"…LCM strategically links P3 concepts, though it differs from other systemic environmental assessment, or evaluation, approaches by its business focus.".."LCM includes liability management, innovation, stakeholder relations, product chain optimization and a focus on cyclic material flows within a product and customer perspective."
(Pedersen, in Hunkeler et al. 2001.)

"(For 3M) LCM involves a screening of the advantages, risks and opportunities of various design options troughout the life cycle. After a preliminary LCM screening, a series of systematic questions are asked for each element in an impact-life cycle matrix…" …"This is done as a repetitive study, carried out to improve business growth, save materials or reduce the level of hazardous substances used. "(Frétière, in Hunkeler et al. 2001.)

"LCM can also be seen as a link between LCA, EMAS and EPD." (Meijer, in Hunkeler et al. 2001)

Christiansen emphasized that LCM is not a tool, maybe a system, but it is mostly a toolbox. (Christiansen, in Hunkeler et al. 2001)

"LCM can be seen as a synthesis of modern management systems. The identified four key elements are bottleneck information, friction removal, shrinking to size and adjustment to demand." (Weidema, in Hunkeler et al. 2001.)

"LCM as a management paradigm has the potential to provide a synthesis of the modern management theories and practices due to its global throughput- thinking approach and its integration of concepts such as life cycle costing, business process re-engineering, product benchmarking, supply chain management, quality function deployment, core competence, learning organisation and empowerment." (Weidema 2001)

"LCM is the extension of the technical approach towards cleaner products and production through amending stakeholder views, by communication and regulatory tracking."
(Remmen, in Saur et al. 2003)

"LCM is a concept of innovation management towards sustainable products, by supporting strategic decision making and product development." (Saur, in Saur et al. 2003)

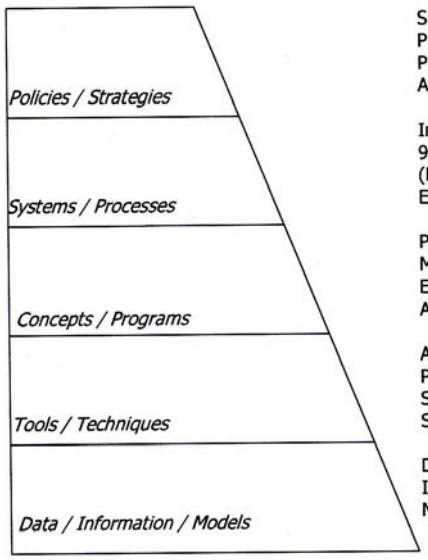
"LCM is a flexible integrated framework of concepts, techniques and procedures to address environmental, economic, technological and social aspects of products and organisations to achieve continuous environmental improvement from a life cycle perspective."." LCM is also described as a management pattern that can be applied on a voluntary basis and can be adapted to the specific needs and characteristics of individual organisations." (SETAC Working Group LCM, in Saur et al. 2003.)

"LCM is business management based on environmental Life Cycle considerations."
(Petersen, in Saur et al. 2003)

"LCM is a cradle to grave approach to thinking about products, processes and services. It recognizes that all product life-cycle stages (extracting and processing raw-materials, manufacturing, transportation and distribution, use/reuse, and recycling and waste management) have environmental and economic impacts. Government, business and non-governmental organisations can apply the life-cycle concept to their decision-making processes related to environment and product policy, design and improvement. The life-cycle approach can also be used as a scientific tool for gathering quantitative data, inventory, weigh and rank the environmental burdens of products, processes and services." … "Related tools to life-cycle management include life cycle assessment, design for environment, life-cycle cost accounting, eco-efficiency, environmental auditing or profiling, environmental benchmarking, environmental performance evaluation, etc." (Environment Canada 2004.)

"LCM is the application of life cycle thinking to modern business practice, with the aim to manage the total life cycle of an organization's products and services towards more sustainable consumption and production. LCM is about systematic integration product sustainability, e.g. in company strategy and planning, product design and development, purchasing decisions and communication programs. LCM is not a single tool or methodology but a flexible integrated management framework of concepts, techniques and procedures incorporating environmental, economic and social aspects of products, processes and organizations. It is voluntary and can be gradually adapted to the specific needs and characteristics of individual organizations." (Jensen & Remmen 2004.)

TABLE 1 Definitions of LCM



Sustainable Development, Triple Bottom line, Integrated Product Policy (IPP), Dematerialization (Factor 4-10), Cleaner Production, Industrial Ecology, Eco-efficiency, Sustainable Asset Management, etc.

Integrated and Environmental Management Systems (ie. ISO 9000/14000, EMAS, EFQM), Extended Producer Responsibility (EPR), Product Development Process (PDP), Certification, Environmental Communication, Value Chain Management, etc.

Product stewardship, Design for Environment, Supply Chain Management, Public Green Procurement, Stakeholder Engagement, Corporate Social Responsibility, Green Accounting, Supplier Evaluation, etc.

Analytical: LCA, MFA, SFA, I/O, ERA, CBA, LCC, TCO etc.
Procedural: Audits, Checklists, Labeling, EIA, etc.
Supportive: Weighting, Uncertainty, Sensitivity/Dominance, Scenarios, Back casting, Standards, Voluntary Agreements, etc.

Data: Databases, Data Warehousing, Controlling
Information: Best Practice Benchmarks, References, etc.
Models: Indicators, Fate, Dose-response, Monte Carlo etc.

Explanations:
EMAS = Environmental Management and Audit System; EFQM = European Foundation for Quality Management; LCA = Life Cycle Assessment; MFA = Mass Flow Analysis; SFA = Substance Flow Analysis; I/O = Input-Output Analysis; ERA = Environmental Risk Assessment; CBA = Cost-benefit analysis; LCC = Life Cycle Costing; TCO = Total Cost of Ownership; EIA = Environmental Impact Assessment.

FIGURE 5 Overview of LCM issues (Jensen & Remmen 2004)

4.1.1 LCM and corporate environmental management

As outlined earlier, the development of the LCM concept has been connected to the method of LCA and also the field of corporate environmental management. Also, according to the vague definitions, almost any environment-related activities could be called LCM. The elaboration of the LCM concept is therefore started by outlining the area of use, since uses for individual organisations as well as for policy purposes have been implied. Also, LCM is discussed in the light of a conceptualization of corporate environmental management, to clarify the relationship of these two concepts and their main similarities or differences.

The use of LCM mainly for business purposes and in relation to business management is implied (see Jensen & Remmen 2004). However, the definition by the Canadian National office of pollution prevention states that LCM can be

applied by governments, businesses, as well as non-governmental organisations to their decision-making processes (see Environment Canada 2004).

According to the definition by Environment Canada (2004), LCM is a concept or an approach that can be used as a scientific tool for collecting quantitative data. Related tools that are mentioned are e.g. LCA, design for environment, life-cycle cost accounting, eco-efficiency, environmental auditing or profiling, environmental benchmarking, environmental performance evaluation. (see Environment Canada 2004.) Most of these tools are, however, applied by individual companies or by companies in a production network, who manage the processes, people and decisions connected to products and services and interact with the demand side of the market. Therefore, the definitions imply that LCM is more applicable from a business perspective. However, the institutional framework can also be significant when creating the infrastructures and regulations, since it defines the operational environment for companies.

The role of LCM as a toolbox for the development of product-based environmental considerations appears in many definitions where the tools are listed (see Meijer in Hunkeler et al. 2001, Weidema in Hunkeler et al. 2001, Environment Canada 2004). The mentioned tools produce or use environment-related information. In many definitions, life cycle management is tightly connected to LCA practices and procedures (see e.g. Environment Canada 2004, Hunkeler et al. 2003). However, LCA cannot be considered a management approach as such, since it includes merely quantitative study and calculation (see ISO14040). The definitions outline also a picture of LCM as an approach, a framework and a way of thinking (see Weidema 2001, Environment Canada 2004, Jensen & Remmen 2004). As a management approach or a perspective, LCM is seen to serve the filtration of life cycle thinking into management practices in general, or even to be a new management paradigm altogether (see Weidema 2001).

The UNEP report (Jensen & Remmen 2004) outlines LCM issues, as earlier presented in figure 5. These levels are not conflicting with the conceptualization of the levels of corporate environmental management presented by Pesonen (2003)(see sub-chapter 3.1), although the contents are elaborated in much more detail by Jensen and Remmen (2004). The contents, although divided into 5 levels instead of the 3 used by Pesonen, follow the same logic of forming a basis on data and tools, followed by programs or processes of development and finally strategic considerations. It is clear that the listing by Jensen and Remmen (2004) aims at an exhaustive listing of approaches and tools connected to LCM. As in some of the definitions of LCM, the tools and approaches listed by Jensen and Remmen (2004) also include company-internal measures, such as environmental management systems, that do not necessarily imply the use of a product life cycle perspective. Since the analysis here does not aim at an exhaustive listing of tools, but rather at finding an interpretation of the overall goal and the related activities, the implied contents for LCM from figure 5. will not be discussed in full detail.

However, this listing also supports the conclusion that there are no radical differences between the current conceptualizations of the contents and tools of LCM with corporate environmental management. Consequently, LCM activities can be understood as a part of corporate environmental management activities.

However, the implied extension of environmental considerations from within the boundaries of one company towards entire product life cycles is specific to LCM and life cycle thinking. Three areas of focus of LCM to "go beyond its facility boundaries" are presented as follows (Jensen & Remmen 2004):

- The product life cycle: flow of materials from acquisition of raw materials to production, transport, use and disposal
- The market: a value and currency flow from the consumer to the producer
- Communication and co-operation in form of exchange of knowledge and experience

Also, Linnanen et al. (1995) note that solving environmental questions in a company and in a product life cycle require co-ordinated activities between all corporate functions, and also breaking of external boundaries of the company. It is clear that LCM is implied to be a meta-level concept of corporate environmental management, including any related development activities from a specific product life cycle perspective. The product life cycle perspective extends the focus to include also intra-organizational co-operation.

4.1.2 The goal and activities of LCM

The development of the LCM concept stems from the efforts to develop more sustainable products and production networks. Therefore it is evident that the overall goal of LCM is also connected to sustainability. Some definitions of LCM refer to sustainability (Saur and SETAC working group in Saur et al. 2003, Jensen & Remmen 2004) and some more specifically to environmental considerations as the goal (Petersen in Saur et al. 2003, Pedersen in Hunkeler et al. 2001).

Since the development of the LCM concept is closely related to the field of environmental management as well as the method of LCA, it is natural that some definitions focus more specifically on environmental considerations.

When compared, the definitions present many types of tasks for companies. However, an interpretation can be made that these aims of being more sustainable or environmentally efficient represent the overall goal of LCM. Based on the definitions, a clear, primary goal for LCM is thus to improve the environmental efficiency of product life cycles so that they will be more sustainable.

Management is defined as "the control and organization of something" (Cambridge Advanced Learner's Dictionary) or the "organization, supervision, or direction; the application of skill or care in the manipulation, use, treatment, or control (of a thing or person), or in the conduct of something" (Oxford English Dictionary). In these definitions, management is clearly seen as specific

activities that are, have been or will be undertaken. It can be assumed that these activities are or need to be undertaken in order to reach the goal set for the management.

If some activities are seen as vital and necessary for reaching the set goals, the existence of these activities can also be regarded as a goal as such. However, a difference made here between goals and activities is that goals are expressions of intentions, and directed towards the future. Activities, on the other hand, are actions that have been, are or will be taking place. Therefore, a two-way inter-relationship between goals and activities is assumed. The setting of the goals directs attention and activities taken towards reaching the goals. The activities taken also affect the reaching of the set goals and the perception related to reaching the goals successfully.

On a more detailed level, the definition of how the aims towards sustainability are controlled and organized by LCM specifically includes a wide variety of considerations, tools and activities (as seen in figure 5), and its meaning as a management approach is vague.

The indications of more practical tasks to be carried out or the use of specific tools can then be interpreted as the activities of management in the LCM definitions. Elaborating more closely on the activities related to LCM is useful, since it gives clear indications of what the LCM approach is, in practice. Also, if the implied activities are seen necessary in order to reach the goal of increasing environmental efficiency and sustainability in product life cycles, planning and organizing these activities can then be seen as the *management* of the life cycle.

Among the implied activities, there is then naturally the implementation of the changes of material and energy flows that can be qualified as environmental improvements. The mentioned environmental improvements include e.g. the design or re-design of processes and products towards being cleaner or sustainable.[2] These seem to be related to technological changes. Also, product chain optimizations are mentioned.

The definitions also strongly relate the activity of implementing improvements to producing and using information concerning the product life cycle. The definitions refer to information on the potential environmental impacts (LCA), costs (LCC) and stakeholder requirements concerning product life cycles. Also, it can possibly deal with information on the environmental efficiency of competitors products or operations (benchmarking), design features or options (DfE) and the relationship of the environmental considerations and business issues[3]. The second, implied activity can thus be called producing and using environment-related information. The definitions

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2 Cleaner products and production refer to improvements where the material and energy intensity of products and processes are improved meanwhile the costs remain constant or decrease and the profitability remains constant or increases (Clift & Langley 1996).

3 "systematic integration of product sustainability e.g. in company strategy and planning.." (Jensen & Remmen 2004)

also clearly imply that LCA is the most important or central tool for LCM, along with life cycle thinking practised on a more general level.

Due to the product life cycle perspective it is clear that information needs extending beyond organisational borders can also concern the markets and societal developments. However, all this information is rarely available, not to mention the references for what products or operations are sustainable. Therefore, if companies want to be proactive, prevent environmental damage and anticipate societal developments, it can be assumed that LCM requires also decision-making in cases of imperfect information.

As discussed previously, it has been suggested that innovations are not generated in simple processes, with cumulative sequences of stages or processes (Van de Ven & Poole 1990), but the processes are rather multiple progressions of divergent, parallel and convergent paths, some of which are related and others are not (de Bruijn & Tukker 2002). Therefore it cannot be assumed, either, that even perfect information and resources would automatically lead to the realization of environmental improvements. The management of the life cycle needs to be therefore interpreted as not only the management of information and its use, but also as any other activities aiming at generating and realizing environmental improvements in product life cycles.

The ISO standard for LCA defines the life cycle of a product as "consecutive and interlinked stages of a product system, from raw-material acquisition or generation of natural resources to the final disposal." (ISO 14040) According to the definitions, LCM is based on life cycle considerations recognizing that all product life-cycle stages have environmental and economic impacts, although they are operated by different companies or actors. In order to collect various types of information on the operations in the life cycle or implement improvements, as implied by the LCM definitions, interaction among various actors and companies is also needed.

As defined in the UNEP/SETAC working group report (Jensen & Remmen 2004), "communication and co-operation in form of exchange of knowledge and experience" is needed. The outlining of LCM issues by the working group report (Jensen & Remmen 2004) also provides a list of approaches and tools implying needs for interaction and co-operation. The perspectives of supplier evaluation, stakeholder engagement, supply chain management, value chain management, environmental communication and industrial ecology (IE), for example, imply some exchange of information or co-ordinated activities among companies and operators. Realizing the improvements can require not only interaction and exchange of information, but also co-ordinated actions among the actors or companies along the product life cycle. The third implied activity for the management of product life cycles is therefore the interaction and co-operation.

Based on the definitions, the three implied core activities of LCM therefore are:

1 Producing and using environment-related information
2 Implementing environmental improvements
3 Interaction and co-operation of actors and companies

The understanding of the organisational features needed or applicable for these LCM activities vary. Some definitions imply continuity or an institutionalization of LCM as an existing entity in a company, which has structures and is active or can be activated when needed. These implications appear in the references to environmental management and quality management, which imply a repetition of studies and procedures, and possibly the use of specific or standardized management systems. (see e.g. Frétière in Hunkeler et al. 2001, Weidema in Hunkeler et al. 2001) Also, a specific product-oriented environmental management system approach has been developed in environmental management (see Rocha & Brezet 1999, Klinkers et al. 1999) with similar implications. The definitions (Jensen & Remmen 2004), however, also state that the efforts need to be systematic in nature, but also flexible. Furthermore, the definition describes LCM as a dynamic process, implying that it can start with small goals and objectives and proceed into more ambitious ones over time.

As a conclusion, many qualitative descriptions of LCM activities are given. It is stated that it is integrated in the business operations and based on voluntary actions. (Hunkeler et al. 2003.) Since LCM covers many activities and the challenges developing LCM practices seem considerable, it can even have corresponding, institutionalized organizations or responsibilities or structures in the organization. The efforts are thus continuous. The efforts also need to be flexible and dynamic, since it can be assumed that the integration of the environmental considerations in any dynamic everyday business operations requires a degree of flexibility and adjustability of activities.

Based on these features and the implied large variety in organizational options for LCM, concentrating on the experiences and thus the content of the activities rather than on the specific organizational forms is seen more valuable. This choice is also supported by the notions that innovation processes and environmental considerations are case-specific, highly dynamic and unpredictable (see sub-chapter 3.4). For this reason, the needed features of the practical organization for LCM activities can also be case-specific, as well as the relationship between the organizational features and the actual outcomes of the projects.

4.1.3 Implications for LCM

Based on the previous discussion, three specific development needs for LCM are identified. First, a more detailed understanding of the environmental improvements is needed, since achieving different types of improvements also may require different types of supporting activities: methods of study, development processes as well as interaction and co-operation in product life

cycles. The elaboration of the defined improvements to be implemented therefore enlightens the other two activities.

Second, more information is needed on the interactive and co-operative practices between actors and companies in a product life cycles. Except for the definition by Weidema (2001), in the LCM definitions there are not many indications on what is the role of learning of actors in reaching the environmental improvements, for example. As discovered in the earlier sub-chapters, in the definitions of LCM the interaction of operators and companies can take a wide variety of perspectives, such as supplier evaluation, stakeholder engagement, supply chain management, value chain management, environmental communication and industrial ecology (IE). Exploring more in detail these concepts from theoretical sources would be an extensive task. The existing tools of environmental management are also often overlapping. Therefore, it has been stated that it is necessary to focus on practical integration of existing approaches, rather than develop new tools for environmental management (see e.g. Baumann & Cowell 1999). For these reasons drawing conclusions on the relevance and relationship of all of the concepts or tools related to LCM would be difficult, and it is suspected that the contribution to the development of LCM in practice would be modest. To develop further an understanding of interaction and co-operation of actors and companies, it is therefore considered more useful to study the actual experiences from an LCM case project, than to explore further the theoretical or literature sources.

The third challenge is then to develop further the understanding on the activities of LCM, and thereby also the understanding of the dynamics affecting LCM practices.

4.2 Environmental improvements

Based on the identified development needs in the previous chapter, the environmental improvements appearing in the LCM definitions are discussed further. The environmental improvements implied in the definitions are discussed according to the implied changes. The environmental improvements mentioned in the definitions of LCM can be roughly divided into three categories according to the implied effects of environmental improvements and references to definitions of innovation. These are process-related, product-related and system- level improvements.

The process-related improvements are referred to as cleaner production. The product-related improvements are product design and development, cleaner or sustainable products and design for environment, DfE. System-level improvements are product chain optimization, design options throughout the life cycles of products and IE.

The references to dematerialization and eco-efficiency in LCM definitions can be interpreted as more general indications of development directions. These appear without specification and can be seen to refer to changes of products as well as to changes of processes, and perhaps even to societal goals. Moreover, and interpretation can be made that these concepts actually refer to the previously identified overall goal of LCM, i.e. increasing the sustainability of product life cycles.

In some definitions the changes that are aimed at are referred to as innovation. The process, product, and system related improvements can be defined as innovations, and doing so, their special characteristics related to environmental improvement potentials and connected social changes can be discussed further. The improvements will be discussed from the innovation perspective in sub-chapters 4.2.3 and 4.2.4.

4.2.1 Process improvements

In the LCM definitions, process-related improvements are mentioned and they are also referred to as cleaner production. Cleaner production can be interpreted as similar to the more often used concept of clean technology, which is discussed with a related concept of clean-up technologies, to demonstrate a difference between these two.

Clean-up technologies are improvements, where assisting technologies or processes are applied to manage the emissions and wastes generated by production processes or systems (Clift & Langley 1996), such as emission filtering techniques and waste water purification systems, for example. Therefore the concept refers to the applications of the so-called end-of-pipe technologies. Clean-up technologies imply processes, where reversing of the harmful impacts caused by emissions and wastes is attempted. The concept draws the focus on the outputs in the system, more specifically at cleaning up the harmful ones. The implied aim is therefore to minimize the amount of uncontrolled harmful outputs and their harmful impacts.

According to thermodynamic laws, materials and energy can change form but cannot disappear. Therefore what goes in must also come out of the process. (see e.g. Pesonen 1999.) With clean-up technologies, the quality and quantity of inputs is not the primary focus of development, but the focus is on the outputs. The changes of outputs then affect also the following processes. The following processes can also be outside the production networks, i.e. in the ecological environments. As a whole, clean-up technologies imply changes from a limited, end-of-pipe perspective, for a limited amount of operators in a network or some of its stakeholders. They can therefore often be considered incremental process innovations from the perspective of a production network of a product life cycle.[4]

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[4] An exception would be a production network, where applying a clean-up technology would signify the change of the actual main product of the entire network, i.e., the functional unit. In that case these changes would be classified as product improvements, according to the perspective and the concepts used here.

Clift and Langley (1996) define clean technologies as technologies that reduce the environmental load of a process without increasing costs, reduce costs while retaining environmental performance, or reduce both costs and the environmental load. The procedures for clean technologies are seen to include good operating practice, input material changes, product changes and technological changes. Therefore, the scope of the change includes changes of inputs and outputs, as well as changes process technology and also activities related to maintenance. These changes can touch several processes in the production network, even entire raw-material manufacturing chains, for example. Also, the perspective can be precautionary and preventive. (Clift & Langley 1996.)

The term good operating practice can be interpreted as process optimizations. Many examples of environmental-economic win-win situations are improvements that optimize or maximize the raw-material and energy efficiency of production processes (see e.g. Esty & Porter 1998). Similar improvements can also be referred to as zero pollution or waste minimization techniques, where the focus is not only on reorganizing the created waste or emissions outputs, but also optimizing the use of raw-materials and avoid the generation of waste and emissions (Nemerow 1995).

Process optimizations imply mainly company-internal changes and decision-making, and therefore also company-internal co-operation. Only one person, however, can also realize optimization type of improvements, given the adequate knowledge and resources to do so. Optimizations can also be sought in co-operation among several companies, in which case system-level changes are implied. These will be further discussed in chapter 4.2.3.

According to the definition by Clift and Langley (1996), clean technology can also refer to changes of product properties. An interpretation of clean technology definition can therefore include all changes to current systems that are both environmentally and economically beneficial. In that respect, the definition of clean technology can be overlapping with the concept of design for the environment, DfE. The difference of a clean process and a clean technology improvement can therefore be significant, since the term cleaner process can imply more a process innovation focus and the term clean technology more a product innovation orientation. Product changes are discussed in detail in the following sub-chapter.

4.2.2 Product improvements

The product-related improvements specified in the LCM definitions are product design and development, cleaner or sustainable products and design for environment, DfE. Related to these, the references to dematerialization and eco-efficiency can be interpreted as indications of overall development directions for processes and products.

Design for environment, DfE, focuses on the functions served by products and services. It also emphasizes a life cycle view, taking into account all potential environmental impacts caused by a product life cycle. (Klostermann &

Tukker 1998, ISO/TR 14062:fi 2003, Stevels 2001.) Therefore, the definitions of DfE correspond to LCM goals quite accurately. Stevels (2001) equals DfE with the concept of eco-design.

There are also more elaborated definitions of DfE, with respect to the different types of innovations sought. Stevels (1997) has presented four levels of product improvements that can be reached through design practices. On the first level are incremental improvements that do not require changes in consumer lifestyles or infrastructures. These can be realized within time horizons of 0-2 years. On the second level are redesigns of existing concepts that can be developed within 0-5 years and require some changes in consumer lifestyles. On the third level, there are alternative fulfilments of functionality, achieved in 0-10 years and requiring changes in both consumer lifestyles and infrastructures. Changes of the fourth level, sustainability, can be achieved in 0-30 years.

Also, the concept of alternative function fulfilment, AFF, refers to a design strategy that can be used to generate new ways of fulfilling a certain function (van der Zwan & Bhamra 2003). AFF has been defined as:

> *"an innovation strategy, which is aimed at reducing environmental impact by embracing the increased design space when focusing on the need that a product system fulfils rather than relying on existing product use routines that are anchored in the society."(van der Zwan & Bhamra 2003)*

Alternative function fulfilment thus implies a critical analysis of the product, the underlying needs and the way a specific need is fulfilled, and requires innovative solutions (van der Zwan & Bhamra 2003).

Another approach to product changes focuses on fulfilling the functions served by the product. This idea has been outlined by the sustainable product-service systems, PSS, concept. These are defined as "An innovation strategy, shifting the business focus from designing (and selling) physical products only, to designing (and selling) a system of products and services, which are jointly capable of fulfilling specific client demands" (Manzini & Vezzoli 2003). The PSS concept then focuses on providing not necessarily the physical product, but the *satisfaction* of fulfilling a corresponding function to the customer. Therefore, with the PSS concept, the target function is not necessarily altered, in terms of this satisfaction. However, the offers for the customer and the consumption process are bound to be changed physically. Developing these types of improvements as implied by the definitions of DfE, AFF and PSS require interaction with the customers and knowledge on the consumption processes.

The abundance of concepts describing the intake of environmental and sustainability considerations in planning, design and development of new products highlight the importance of the product-based perspective. The concepts are overlapping, and have in common the product-based focus on the development efforts. They describe incremental or radical changes of the functional unit products of a production network as goals for development work. Therefore they also imply interactions and co-operation among companies participating these networks. With changes of products, often also

the customer perceptions need to be considered, and these concepts therefore also imply needs for interaction especially with the customers and end users of the products. Thus, with the improvement concepts focusing on the product properties, the system boundary of the changes in terms of information, technological changes and also interaction and co-operation is emphasized and extended towards the customer and user phases in the life cycle.

4.2.3 System-level improvements

The LCM definitions refer to improvements that have a potential to change the material and energy flows in a vast number of processes in a production system. Product chain optimization, design options throughout the life cycles of products, sustainability and industrial ecology, IE are mentioned. Product chain optimizations clearly refer to incremental process changes in the network, but also implications for more radical innovations touching entire production systems or industrial systems can be found.

Some definitions give LCM an underlying goal of developing industrial ecology, IE, by stating goals of cyclic material flows and connected product systems. When the flows of materials and energy are optimized, connections between product systems are often considered. Product systems are also often interlinked or dependent on each other and cyclic solutions can be both environmentally and economically efficient (Allenby 1999, Ayres & Ayres 1996, Ayres & Ayres 2002). The concept of industrial ecology implies a focus on industrial systems and also needs to develop network co-operation (see e.g. Hämäläinen 2005). However, the focus of LCM is defined to be the life cycles of an organization's products or services (Jensen & Remmen 2004). The system boundary focus of LCM is therefore, in most cases, by nature narrower than that of an industrial system. Consequently, developing industrial ecology may not be the primary goal of LCM, although these concepts are very similar and LCM could be considered a helpful step in reaching for IE. In any case, LCM and IE have common features since both aim at sustainability, imply needs to develop network co-operation and may imply system-level changes.

de Bruijn and Tukker (2002) summarize presentations of innovation from a system perspective. They outline three levels of system changes: system optimization, re-design and innovation, as presented in figure 6.

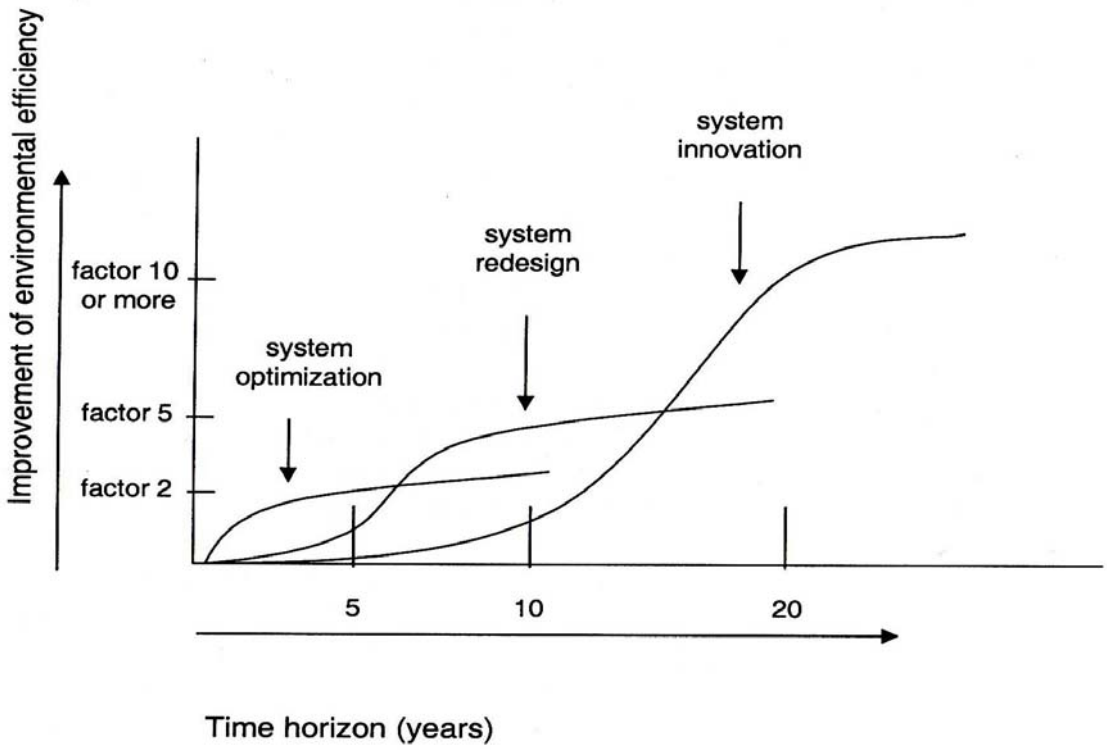

FIGURE 6 System optimization, re-design and innovation (RAND 1997, Weterings et al. 1997, as presented by de Bruijn and Tukker 2002)

When this representation is compared with the environmental improvements targeted by LCM, implications for improvements on all three presented levels can be found. Clean-up and end-of pipe technologies can represent incremental optimisations of a system, as well as product chain optimizations. Based on the definitions of clean technologies, it can be assessed that they can represent either system optimization or system redesign level improvements, depending on how central technologies the changes target in the industrial system and how competence-destroying the developments are. Product innovations can also represent system redesigns. However, more radical product innovations such as a shift to a product or product concept that can be assessed sustainable, with DfE, PSS or AFF solutions can represent system-level changes, if they are redesigns of products that are central to the industry. Also IE solutions are by nature system-level innovations, since the focus is on the development of entire industrial systems. When defined as innovations, the environmental improvements brought by LCM can then refer to any level of these changes.

It can be concluded that many definitions of environmental improvements targeted by LCM are overlapping and somewhat ambiguous. Decisive conclusions cannot be made on their effects on the material and energy flows of a production network or the brought environmental improvements. However, the definitions can be analysed with concepts from material flow models and innovation literature. Consequently, environmental improvements in a product life cycle can be perceived as a variety of incremental or radical process, product or system innovations. These changes have a certain scope of how

many processes they affect, and the life cycle perspective can thus correspond to a system level perspective on innovations. The environmental improvements, however, even if defined as innovations, do not only imply technical changes but also changes of social processes. The conceptual analysis therefore implies that for managing these changes a focus on interaction and co-operation of actors and companies as well as on innovation activities in production networks are significant.

Instead of the specific concepts describing these environmental improvements, the environmental improvements brought by LCM could also be defined as the controlling (end-of-pipe/clean-up), reducing (optimizations) and prevention (DfE, sustainability) of the material and energy flows causing the harmful environmental impacts in product life cycles.

4.2.4 Implications for LCM

The comparison of the concepts describing environmental improvements in LCM brings some implications for the two other activities of LCM. First, producing and using environment-related information may hold different types of challenges related to different types of environmental improvements. Second, organising the developments for different types of improvements may also require different types of solutions.

Simple improvements of material and energy efficiency merely decreasing resource use can directly be interpreted as environmental improvements. Rennings states, that the criteria of environmental attribute of an innovation is that they reduce environmental burdens at least in one item (Rennings 2000). However, there are questions of the availability of data on current operations, of perception and understanding, and also of the time perspective of the changes, that in many cases hinder the complete and reliable evaluation of the actual environmental effects of changes.

As experienced with LCA procedures, complete information on the inputs and outputs of technological changes and their impacts is rarely available. Production networks of product life cycles are vast, and process data is often linked to competitive considerations among actors and is therefore confidential. Also, the procedures are complicated and the reporting and interpretations for decision-making cannot be straightforward and fully transparent. (see Baumann 1998, De Beaufort et al. 2001, Frankl & Rubik 2000, Heiskanen et al.1995, Loikkanen et al.1999, SETAC 1992.) The evaluation of environmental efficiency is complex and decision-making requires value judgements and trade-offs among economic and environmental values. These considerations are highly case-specific, and may require information on stakeholder preferences, for instance. Therefore, it can be suspected that the information needs of LCM cover not only data on material and energy flows, i.e. LCA data, but also other types of information, such as information on value judgements and preferences.

The expected realization time of improvements (see figure 6) affects the availability and reliability of data. For changes, that need longer time periods for realization and alter entire industrial systems radically there is often no

complete or reliable data available. With material flow study and LCA methods, the changes of material flows of some incremental or short-term technological changes can be quantitatively simulated to some degree of reliability with scenarios, for example. It is impossible, however, to acquire LCA- type of accurate process data for radical changes of entire product life cycles or industrial systems since these many have thousands of inter-related variables. Therefore, with the realization time of the changes, the level of uncertainty on the material and energy flows can also be expected to grow.

Thus, the assessment of the potential environmental impacts of product life cycles can be expected to be more challenging for studying the impacts of more radical innovations and changes of entire industrial systems. The possible problems in collecting and using LCA data, for instance, indicate that the needs to collect information for LCM but also the using of environment-related information are related to interaction and co-operation. Co-operation can be helpful for the collection of data, but also for the interpretations needed for decision-making and for dealing with the related uncertainties.

In the developed quantitative approaches to study environmental impacts, there are also questions and restrictions of perception that affect the formed understanding of environmental realities based on quantitative results. The descriptions of impacts through data can also be limited or biased. (see Schneidewind 2003.)

The environmental improvements targeted by LCM imply that many environmental improvements have a system boundary wider than that of one company. Some incremental optimizations can be realized as internal efforts in companies. However, with changes of products, for instance, also customer and user perspectives need to be considered. Especially for wider system-level changes or more radical innovations targeting sustainability, extensive co-operation needs are implied.

Interaction and co-operation can be needed within or in-between companies and other actors, that are affected by the production networks to realize improvements. de Bruijn and Tukker (2002) state, that for system innovations there can be new actor constellations and actors roles and their activities can considerably change. System innovations are therefore not only multi-level, but also multi-actor processes. As also indicated by Roome (2001), the wider the sphere of influence of the innovation in technological aspects is, the wider the social sphere of influence also seems to be. The processes of technological and social change thus seem to be intertwined.

The activities of implementing environmental improvements are closely connected to the producing and using environmental information and also of organising the necessary interaction and co-operation within and in-between companies. In the definitions and literature of LCM, there are many references to LCA and to other tools that can be used to collect information and also many references to concepts describing interaction or co-operation of companies. However, there are very few experiential accounts available on what other types of information than LCA results have been needed for LCM activities,

how the information has been collected and how the supporting co-operation processes have been organized.

Rikhardsson and Welford (1997) have concluded that the dominant body of knowledge employed by corporate environmental management is based around technological sciences. The found descriptions of LCM also seem to be dominated by the perspective highlighting the possibilities brought by quantitative studies and technological changes, and not so much exploring the potential or importance of the interaction processes affecting these developments. However, seeing environmental improvements in a product life cycle as different types of innovations highlights a necessity for increased interaction and co-operation in the production networks concerned. Due to the complexity of the innovation processes on a micro-level (see sub-chapter 3.4), the significance of interaction and co-operation in LCM practices therefore needs to be studied further.

5 DESCRIPTION OF THE CASE PROJECT

In this chapter, the organization and process of the case project are outlined. These serve as background information for the thematic discussion on the findings. The description of the organisation and also a narrative describe the specific context in which the studied interaction and co-operation occurred in the case project.

The case project was accomplished in collaboration with a research team from VTT, the Technical Research Centre of Finland, the Association of Packaging Technology and Research PTR, the three largest Finnish breweries, two largest retail chains and several other companies in the production network of beverages, including many producers of packaging and packaging materials. The project lasted from 2000 to 2003.

The goals of the project were to study the environmental impacts of beverage packaging along their life cycles, i.e. LCA research, and also to create organizational schemes for the respective environmental management within the companies. The set goals will be discussed in more detail in sub-chapter 6.1.

In the LCA, the packaging for 0.30l and 0.50l glass bottles, aluminium cans and PET bottles for beer, cider and carbonated soft drinks were studied. Also larger packaging for refillable and recyclable 0.75l glass bottles for wine and 1.5 l PET bottles for soft drinks were studied, but they were reported separately. In the assessment of the individual systems the chosen functional unit was 10000 litres of beverage consumed. (see Virtanen et al. 2002.)

5.1 The Organisation

It was explicitly stated in the documentation of the case project, that the primary goals are the production of environmental data and environmental improvements and that the co-operative process aims at consensus and democracy. These communicated to the participants that the decisions should be based on a common understanding and common interests served. It was

clearly implied, that the possible conflicts of interest or disputes caused by market situations, power relations and economic preferences should be set aside to reach the defined goals. Also the specific forms of organisation of the project aimed to support the spirit and possibilities for interaction and co-operation. Co-ordinators and chairmen of meetings had important roles acting as mediators in cases of threatening conflicts.

With the shared definitions of goals, and the formal organisation of the process, as well as the actions of the co-ordinators and chairmen, it was explicitly communicated, that the context of the co-operation was not and should not be similar than in the relationships between the actors and companies normally. The co-operation was therefore meant to set aside previous conflicts and focus on environmental considerations.

Of the organisation of the case project, three features that formed the specific context for co-operation were thus identified. First, the process was initiated by a careful process of goal definition and commitment building. Commitment and carefully defined goals aided creating the basis for co-operation and maintaining it in-between companies. Second, in order to generate communication and development in both the networked economic environments and also among the highly specialized tasks within companies, a cross-functional and cross-organisational participation was needed. Third, the scientific and practical co-ordinators and chairmen of the meetings acted as mediators between operators and companies. These are shprtly described in the following sub-chapters.

5.1.1 Commitment building and goal definition

The idea of organizing a joint effort of the related industries was introduced to the suggested participants by the scientific co-ordinators. The principles and benefits of the approach were presented with proposed financing and division of work. The costs were divided among the participating organisations according to a principle of expected utility, taking into consideration also the size and resources of each organisation. Expected utility was defined as significance of possible applications and benefits from the study. This type of division of costs was considered especially advantageous for small and medium-sized companies, enabling their participation in an extensive LCA project.

Careful negotiations and active dialogue among the participants in the start-up phase served the building of commitment in the project. Although the study required significant resources from many participating companies, the actual research setting or the set goals were not criticised afterwards. The results and their representation, were, however, criticised. This was also expected due to the economic interests involved. Commitment of participants was expressed through an active attendance in meetings, including most of the management level participants. Also extensive efforts that were made for data collection by each participating company, also unplanned ones, signalled for a high level of commitment. The carefully defined goals for the project also

helped focusing the efforts when difficulties were met, especially in data collection and with conflicting interests.

5.1.2 Cross-functional and cross-organisational participation

The case project was organised in a way, that it involved a large number of operators in active work for the project. There were participants from most of the important companies in the production network, but also participants from all relevant organisational levels. The actions taken were organised in working groups, as presented in Figure 7.

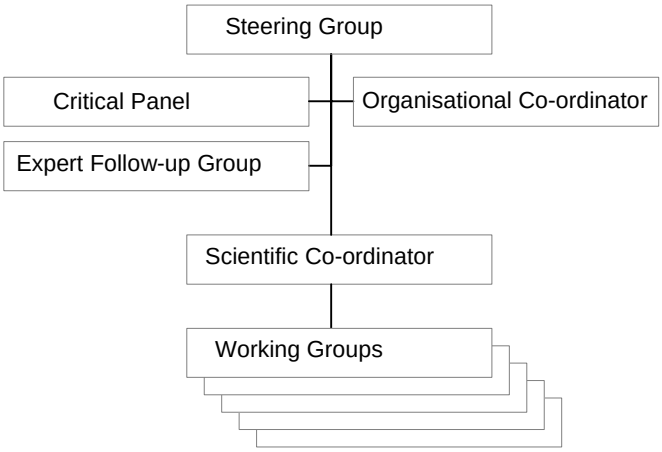

FIGURE 7 Overview of the project organisation (Poikkimäki & Virtanen 2003)

The steering group had an essential role in building the needed level of democracy in the process and maintaining consensus and commitment by defining the common goals, scope, resources and code of action. Also, the active participation and interest of the management level communicated a commitment of the participating companies to the process, which seemed valuable.

Along the case project, with the exact LCA data on their processes, the steering group defined the state of operations and a specific level of environmental efficiency in the product system that it could commit to, now and for a period of five years. The purpose for the LCA study was that the results would be applicable from 2000 to approximately 2005. Representations of technologies that would soon be replaced were excluded from the data. This procedure also provided the employees of each company with clear statements of what is the expected minimum level of environmental efficiency in the operations. Such procedure also provided other operators in the production network with important information on the development pace within the network, which could be important for buyer-seller relationship development and also for benchmarking among competitors.

Another important role of the steering group was to sign legal contracts and agree on the forms and contents of the external communication. A joint

statement of the possible applications of the study was also drawn and signed by the steering group and used for data collection from organisations that were not participating and thus not aware of the goals of the project.

The steering group chose the Finnish Association of Packaging Technology and Research, PTR as co-ordinator of the study. The organisational co-ordinator managed the financing, legal contracts and agreements, internal and external communications, meetings and seminars.

The scientific co-ordinator was a research group of VTT Processes of the Technical Research Center of Finland. The team acted as principle investigators and advisors of the work of the field groups and carried independently the responsibility for the scientific actualisation and content of the study. It drew questionnaires for data collection, based on flow sheets outlined in the working groups. The research team presented the progress and results to the steering group and the expert follow-up group regularly. The team also documented meetings and decisions of the steering group and other organised groups within the study. The most important decisions taken concerning the practical realization of the project were discussed and approved by the steering group. Similarly, the scientific decisions were discussed and commented by an expert follow-up group. The overall quality of the study was assessed by a critical panel.

The appointed co-ordinators and chairman of the steering group took responsibility of reminding the participants of the fact that without a certain level of commitment, consensus and willingness for positive interaction the process will not work and achieving the set goals is compromised. The economic interests and their influence in the process were openly discussed, with a premise that they were not allowed to interfere achieving the defined goals of the project, that were environmental.

Working groups were formed for the main phases of the product life cycle, i.e. logistics, brewery, and retail. These groups worked in collaboration with the scientific team. They were explained the methods used and they formed overall views of the studied processes and affecting variables, drew plans of action and delegated responsibilities for data collection. Due to the confidentiality requirements no data exchange took place between the different work groups. However, some working groups agreed on data exchange among themselves, meaning that the breweries and the retailers participating could benchmark the environmental efficiency of their processes with the competitors' processes.

Due to unexpected delays and problems in retail data collection, an additional retail seminar was organised as an extension to the retail working group. The participants were from the steering group, the retail working group and employees responsible for the data collection. As a conclusion, additional scenario variations, measurements and tests were decided upon.

An expert follow-up group was called in order to ensure the scientific quality of the study. Participants of the group were representatives from the steering group, non-governmental organisations, independent LCA experts and the scientific research team. Additionally, participants from working groups

were called when necessary. The most important methodological choices were discussed and suggestions for the most justified methods to be used, noted needs for additional data and reporting the limitations were made, for example. A clear benefit was that the group made suggestions concerning the most controversial choices. This helped the research team remain independent and keep a consensus-building role among the conflicting interests, while carrying the primary responsibility for the scientific quality.

The scientific co-ordinators emphasised conducting the LCA according to the requirements and spirit of the ISO standard (see ISO 14040). In practice, this meant iterations and constant verifications of the used data and methods, and also balancing between political pressures and varied interests.

Towards the finalization of the study, a critical panel was called to discuss and validate the results and interpretations of the LCA. The panel met twice. There were participants from many connected interest groups: breweries, retailers, packaging manufacturers, industry organisations and non-governmental organisations. For the revision of the study, all participants signed confidentiality agreements. Interest groups worked independently and drew critical statements of the used methods, data and possible interpretations. The critical statements were attached to the final report of the LCA study. The chairman of the critical panel also acted as an independent peer reviewer of the study, following the procedures described in the ISO standards (see ISO 14040).

The phases of the case project (see figure 8.) were implemented somewhat in the presented order, but especially in data collection the study proceeded as an iterative process with repeating phases. The phases were not identical to a basic LCA process described in the ISO standards (see ISO 14040). All of the standardised phases were, however, in-built in the process. The process aimed at an integration of the LCA procedures in a continual development spiral, as described in the standard on environmental management systems (ISO 14001).

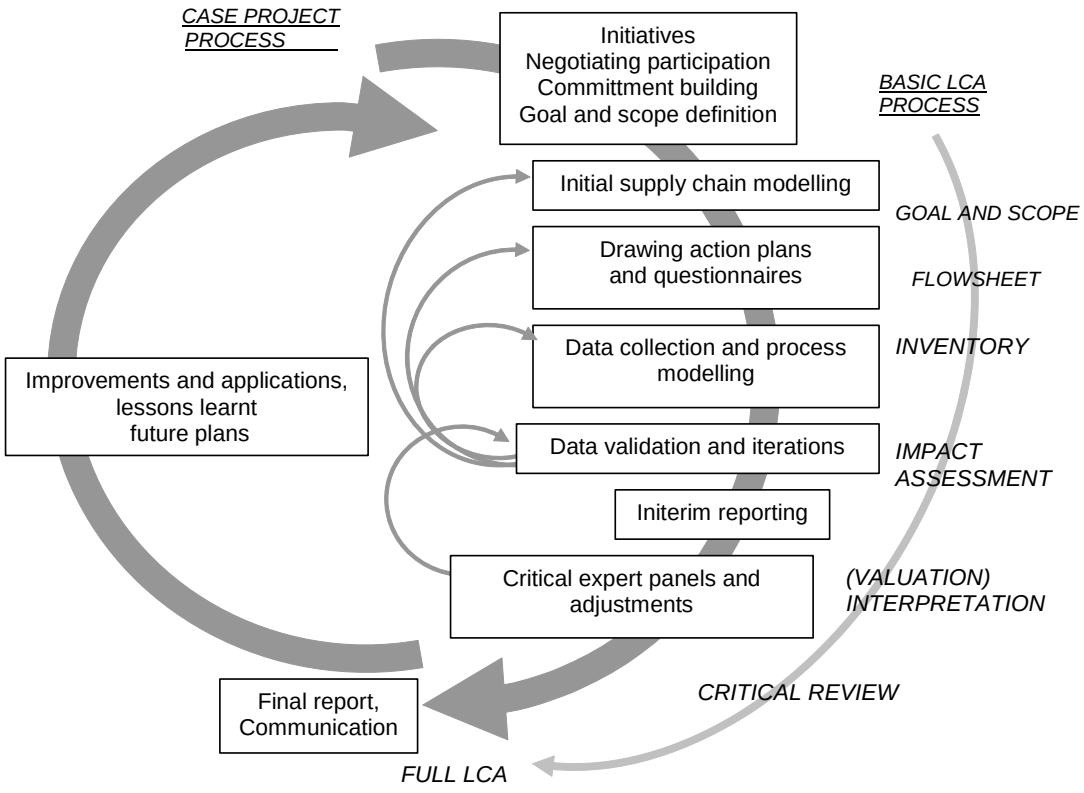

FIGURE 8 The process of the case study and the parallel phases of a standardized LCA process

In addition to the standardized LCA phases, there were many activities connected to the collection of information and managing the co-operative process. For instance, the phase of initial modelling of the production networks included the drawing of flow sheets by the researchers. These were then elaborated with the people operating the processes in practice. Action plans for data collection were drawn for the operators as well as detailed questionnaires for data collection. The collected data was then validated during iterative rounds. The collected data was constantly checked and verified against other sources and data collection efforts were repeated to complement and support previously collected data.

Towards the end of the project, possibilities to start new LCA projects were discussed. Some of the involved companies launched new LCA projects, of which the most significant one was the study of the malt barley and beer life cycle (see Virtanen et al. 2006). Thus, there was a new round of LCA process for these companies.

The forming and participation of the organised groups and primary responsibilities along the process are presented in figure 9.

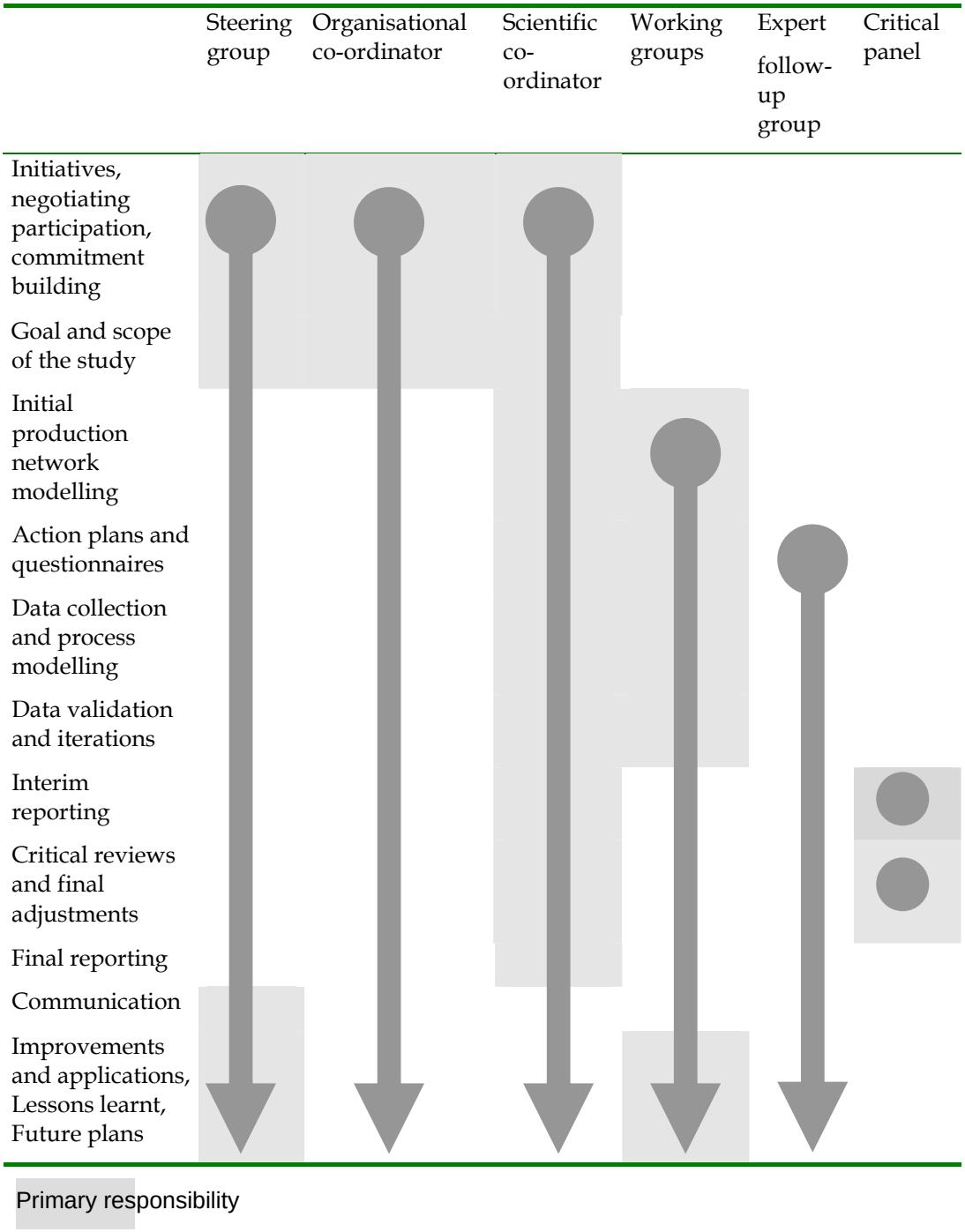

FIGURE 9 Participation and primary responsibilities of the project organisation (Poikkimäki & Virtanen 2003)

5.2 The Process

In this sub-chapter, some important dates describing the process of the case project are first listed, and then a researcher's narrative describing the process is presented.

5.2.1 Some important dates

30.8.2000 A research plan was finalized and the project was started.

3.10.2000 The Steering group had the first official meeting. The Steering group met regularly throughout the project, approximately once a month.

28.11.2000 The Finnish Parliament gave a statement that the taxation for all beverage packaging needs to be renewed. It was also stated that a life cycle assessment needs to be carried out as a joint effort of the authorities and related industries, to provide the needed information for the decision making.

13.12.2000 The Expert follow-up group had the first official meeting. The expert follow-up group met regularly throughout the project.

17.1.2002 The First meeting of the critical panel took place.

8.2.2002 The Second meeting of the critical panel took place.

15.5.2002 A Press conference was organized to present the results of the study. An active discussion on the results in the publicity followed. Many of the related interest groups published their own interest-based statements or articles on the results, e.g. Laitilan Wirvoitusjuomatehdas (a Finnish brewery) and the Finnish Food Marketing Association PTY. Also a consultant company seeking media attention published a statement on the use of LCA for policy decisions. The media also participated in the discussion, e.g. Helsingin Sanomat and Talouselämä.

An additional report documenting the organization and process was published in the beginning of year 2003.

5.2.2 A narrative

To initiate the case project and to draw a research plan that all participants could accept had required several rounds of meetings by the key actors. The idea and initiative for the approach with a joint effort among the related industries came from the scientific co-ordinator research team.

Negotiations with possible participants of the case project were organized to discuss terms for participation, goals and scope of the study around March

2000. The negotiation phase then continued until August, and the negotiations on the definitions of goals and actions taken continued also after the launching of the project, at the end of the year 2000.

I began my work in the case project in November 2000. I worked actively in it for a year and then participated in many meetings and reporting also later on, up to the end of the year 2002. My responsibilities included the participation in the steering group meetings as well as many of the working group meetings. I was responsible for organizing the data collection on the retail operations in co-operation with the participating companies. My responsibilities also included data collection on many accessories and transport packaging. I also participated the scientific modelling of the processes and reporting.

From the beginning of the case project, it was obvious that there are strong personalities among the participants, significant economic interests involved and also potential conflicts. However, the co-operation was mainly polite to the surface. There were many nuances in the interaction to be observed and many things that were not explicitly discussed. It was also quite clear that the dynamics of interaction among the actors has an effect on the actual LCA research process and I found it highly intriguing why and how this can occur. Therefore, I made the first notes on interactive situations and quotes of comments by the actors merely for fun.

A note from the third steering group meeting states a curious atmosphere. There was a will and determination to carry out this common project, but also an underlying tension. Most of the applied funding was received and the participants were very content about that, but eager to discuss the challenges undertaken in much more detail and outline the rules of practice.

The most important observed drivers and motivations for the beverage packaging case project were the threats or possibilities posed by the planned changes in taxation. The most important threats that were affecting the co-operation seemed to be the conflicting economic interests.

Many of the first notes are connected to the discussions on the participants and their possible interests. There was a quite strong common motivation to carry out the project because of the expected changes in the taxation of beverage packaging that could be affected by the LCA results. The observed, most apparent interests of the key participants are listed as presented in Figure 10. It was documented that the organizations participating in the project were expecting valid, up-to-date data on environmental loads of packaging. Also, it was assumed that all participants wanted to develop practical and environmentally sound packaging, as stated in the commonly accepted research plan. The business companies were also considering the possible implications on competitiveness.

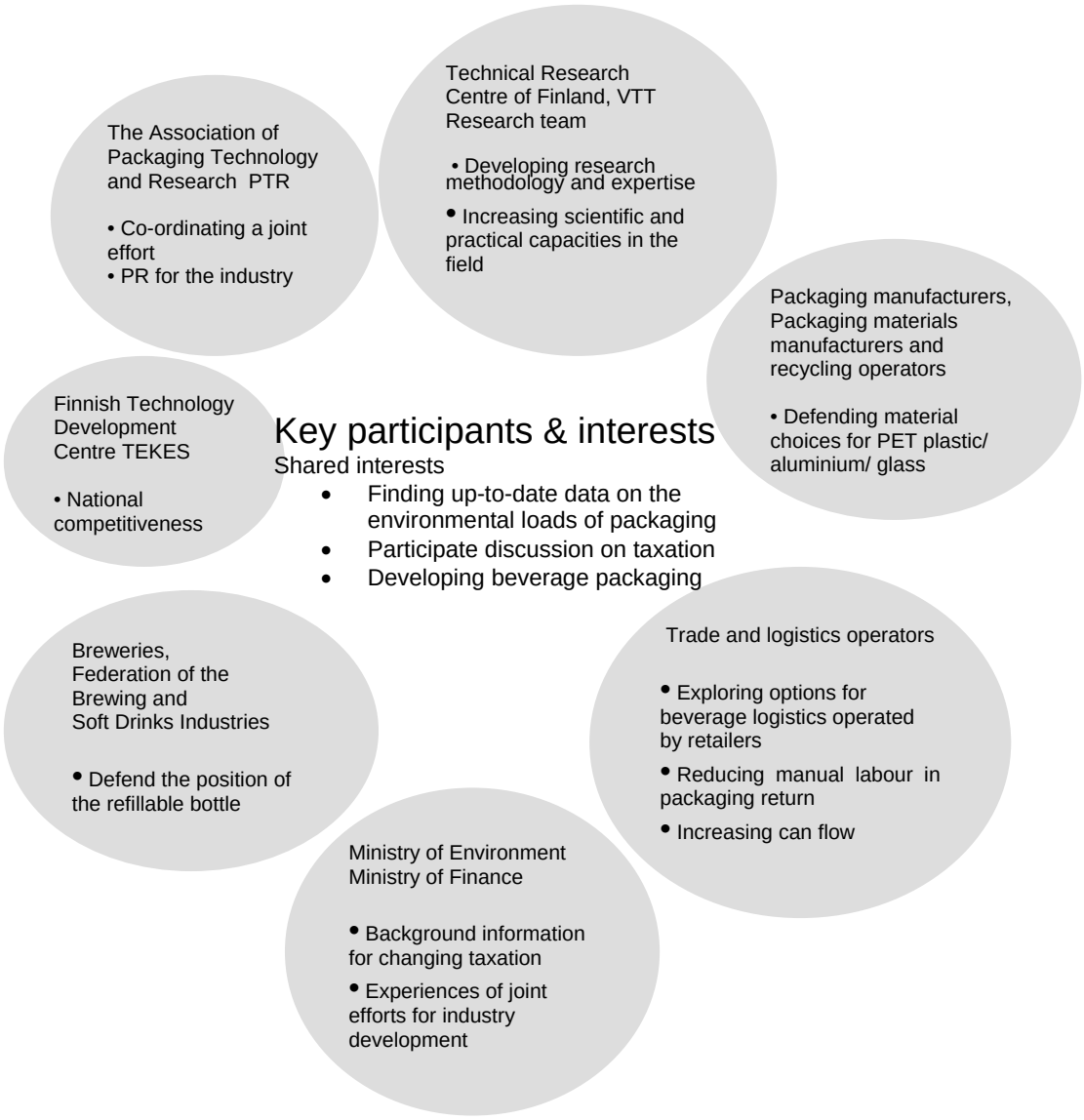

FIGURE 10 Key participants in the beverage packaging LCA study and related interests

In the beginning, there were many discussions on what companies should and can be included in the project. The notes demonstrate the formation of "the group included in the project" and "the companies left out".

> *Note 1. 12.2.2001. Steering group.*
> *- (Researcher:) "We need to include also the small and medium-sized companies. (Due to the requirements of organizations funding the project) The questionnaires will serve them, too."*
> *-(Industy representative:) "The report can specify how the results will serve the small and medium-sized sector."*

The participating companies allocated resources and found the responsible persons for the data collection efforts. The possible organizations for the working groups were discussed and decided by the steering group. Also the principles to be followed, e.g. the confidentiality of data, were discussed and agreed upon.

Meetings of the steering group and the working groups were held to negotiate the details of what will be done, and to initiate the data collection. Also, in the beginning meetings for building consensus on the goals of the project were organized. Some notes testify that "common ground" was built also by discussing attitudes and principles for practices.

> *Note 2. 12.2.2001. Steering group.*
> *A discussion on what is the attitude (of the participants) towards the taxation in other countries.*
> *- "The different functionality of different packaging materials need to be taken into consideration."*
> *The taxation of beverage packaging in Germany is discussed. Conclusion: valid LCA information is more valuable and more likely to direct into the right direction.*

> *Note 3. 13.12.2000. Expert follow-up group.*
> *A discussion on previous studies, of which the results were not accepted by the steel industry. And a discussion on possible allocation and crediting procedures to be taken. It's discussed how to do things in the LCA. Many different perspectives presented. A consensus formed that these will be discussed with more data to illustrate the effects of choices as they appear.*

> *Note 4. 1.12.2000. Brewery working group meeting.*
> *-(Industry representative:) "Wastewaters from breweries are wanted stuff"*
> *In the meeting, the quality of the material flows is discussed. It is agreed on where the different types of data will be collected and how. And by whom.*

The data collection was organized in different ways for different industries. Working groups were organized for this purpose, separately for breweries, retailers and logistics. The management level participants from the related industries took part in the working group meetings occasionally, in the beginning and also towards the end of the data collection. Otherwise the meetings were held mainly by the researchers and by the people operating the processes or responsible for collecting the data.

There were many discussions on what type of data will be needed and where it can be found. The LCA format was familiar e.g. to the breweries, since they had participated also in a previous LCA study. However, the data requirements were novel to the retailer companies participating in the study for the first time. It was observed that in some cases, even within the same company the management level participants had quite a different view on what data can be found in the information systems, for instance, than the people responsible for operating the processes or collecting the data in practice.

> *Note 5. 10.2.2001. Meeting with a retailer company.*
> *Issues of data collection are discussed. Manager X has a very different perspective on what data is available. Person Y (from the same company, responsible for data collection) stays mostly silent. But states that some data cannot be found in the information systems, the way the managers suggest. Some market researches as data sources are discussed. The managers do not fully grasp what type of data is needed for LCAs.*

After the initial talks, the researchers prepared flow sheets and questionnaires for finding out the inputs and outputs of each process in full detail. The questionnaires were improved with comments from the industry representatives. It was observed that the extent of data and details needed was

in many cases a shock for the people responsible for delivering it. In fact, in most cases they were ordered to deliver the data by their managers. Some tensions could be observed in the data collection phases, due to misunderstandings and the efforts needed. However, there were also some actors in the participating companies that proved to be highly committed to carrying out the tasks and also very interested in the studied issues. A general note was made during the data collection that the attitude towards environmental considerations "in the field" in retail operations was very positive and many actors were interested and motivated to work for "greener" development.

In the retail operations, after some discussions it was clear that much data needs to be collected in the field, through follow-ups and measurements. Periods of observation in the shops of different sizes were organized. The shop personnel were introduced the idea of the study and the questionnaires to be filled in, including e.g. statistics on the refilling of the self spaces or cooling cabinets and on faulty, broken or stolen beverages etc.

Other examples of the data collection procedures were e.g. weighing the packaging and analyzing the aluminium contents of the can materials in more detail to discover the amount of recycled contents in the can and its lid. The logistics working group worked on a separate model of the routes of beverage logistics, types of vehicles used and actual loads along the loading and unloading of the vehicles, for instance.

The project then proceeded through rounds of data collection and processing, meetings of the working groups to discuss and verify the LCA findings, and additional collection of data and calculations. Parallel to the data collection activities, the research team carried out the scientific tasks of modelling and reporting. While discussing the data and the related processes, the working groups found ideas for environmental improvements that could be realized. Some examples of these can be found in sub-chapter 6.1.2. In the working groups, some data was also shared among competitors for benchmarking of processes and verifying the data.

The steering group was regularly presented preliminary results and updated information on the different phases of data collection. Also, in some cases additional resources were allocated by the steering group members for data collection. Questions related to the scientific validity and the made decisions in data collection and modelling were discussed in the expert follow-up group. The working atmosphere in the expert follow-up group was considered good throughout the project.

Some essential variables used in the LCA calculations were constantly discussed and argued upon in the steering group, due to their significant effect on the results. For instance, the refilling rate of the 0,33l brown glass bottle and the allocation and crediting of the recycling of materials were discussed on several occasions.

The definition of the refilling rate affected the overall efficiency calculation of the glass bottle system. Therefore, a high refilling rate would underline the

benefits of the glass bottle system, in which the breweries had invested. A lower refilling rate, however, would improve the comparison for the aluminium can. The can would be an option preferred by the retailers because of the efficiency of the return system, where the cans are crushed when returned, and need no manual labour for the sorting. Also, decreasing the higher taxation that the aluminium can had, would bring possibilities for increasing the amounts of imported beer. This variable and the related interests were among the most significant observed sources of conflicts in the project.

Based on reliable long-term statistics on the glass bottle system and much verification, a refilling rate of 32.16 times was found. But despite of the reliable statistics, this variable was constantly argued.

> *Note 6. 8.2.2001. Steering group meeting.*
> *The refilling rate of bottles discussed for the third time. The subject is brought up by an industry representative. Researcher X explains and justifies the basis of calculations. Patiently. Chair person disrupts.*
> *- (Chair person:)"This can be accepted."*
> *(Some almost loose their nerves)*
> *- (Industry representative:) "This (discussion, argument) is only to protect the glass bottle pool!"*

Many points of argument seemed to be, however, the expected ones. There are notes of several occasions such as the previous one, where chairman of the steering group, the researchers or the co-ordinators took the mediator role to avoid too serious conflicts in the discussion, so that the co-operation could continue.

In addition to the internal tensions to the project, also pressures from outside the participating organizations were faced.

> *Note 7. 4.12.2001. Email & internal researcher meeting.*
> *Pressures from industry to include interest-based scenarios are discussed. No scientific basis to include them, so it's decided to leave these out. It is difficult to communicate this to industry representatives, they do not (want to?) understand the difference in exactitude and reliability between "as it is" and fictional/optimal scenario.*

> *Note 8. 27.9.2001. Internal meeting of the researchers.*
> *There are pressures from material manufacturers for the crediting of the recycling of materials. They provide many types of additional information.*

As an opposing force to the tensions, a note was made that the participants were very much expecting to see the initial results. In some cases, the results were found very surprising. For instance, it was found that the cooling of beverages at the retailers is both economically and environmentally a very significant burden. Many participants of the steering group also seemed to develop a genuine interest towards the subject and environmental considerations in general. A note verifies that the personal motivations expressed by the participants had various reasons: for some environmental work was motivated by the changes in the business environment and for some the motivation was created through pressures from a teenage daughter with demands for ethical conduct and environmental considerations.

Towards the end of the project, an initial draft of the final report was produced and discussed by the steering group. Also a critical panel event was organized.

> *Note 9. 17.1.2002. Critical panel meeting.*
> *(An NGO member:) - "The results need to be repeatable. Just give me the data. If you cannot give it publicly, the study cannot be relied on."*
> *> The person offers to make the calculations*
> *(Researcher interpretation:) There are participants in the critical panel that simply do not understand the extent of this LCA even after it has been explained.*

In the event, some disagreements were verbalized. There were also discussions that were useful for improving the final report. The initial draft of the report was corrected according to some critical comments and finalized to include all the necessary details. Each interest group supplied their critical statement. Also a critical review was done by an independent expert. All the critical statements were then attached to the final report. The results were presented at a press conference.

At the same time with the official releasing of the results, some interest groups presented press releases with their own interpretations of the results. This was contrary to previous agreements. It had been agreed that only the coordinator will release the official interpretation. There were many interest-based discussions and consequent conflicts after the release of the results. Also some parties external to the project made commentaries on the results, for instance consultants seeking media attention.

> *Note 10. 16.5.2002.*
> *A company protests. They had commented on the draft of the final report but not participated in the critical panel seminar. Hearing about the press release, they are afraid that the final report includes confidential information and threaten to take legal action.*
> *(This was an international company, which was not participating in the study and of which the data was not represented in the final report.)*

The results from the LCA study on Finnish beverage packaging systems were interesting (see Virtanen et al. 2002). An overall conclusion was made that all of the packaging systems have environmental impacts and the impact potentials and impact profiles vary for different packaging. Therefore, the question of which packaging is environmentally most efficient, could not be unambiguously answered. The conclusions on the environmental advantageousness of different packaging systems depend on the selected aspects; i.e. the priorities set for the impact categories. However, for the setting of these priorities there are no commonly accepted methods. Therefore, it was reminded that the choice of the aspect and its reasoning will vary depending on the context where the results will be used.

In the comparisons, the 0.33l re-fillable glass bottle caused less acidification, global warming, and especially photochemical formation of tropospheric ozone than the 0.33l aluminium can. However, the difference between the systems was insignificant for nutrient enrichment potential. Concerning oxygen depletion, the standings were the opposite and aluminium can was less burdening than the glass bottle.

The results were similar among the packaging materials for the 0.5 l packaging, except that the difference in the nutrient enrichment potential was slightly in favour of the aluminium can. The 0.5l re-fillable PET bottle was less burdening for acidification, global warming, photochemical formation of tropospheric ozone, and nutrient enrichment, when compared with the 0.5l aluminium can. The aluminium can system causes less oxygen depletion potential.

Some of the most important findings were that the cooling of beverages at the retail shops increased considerably many of the emissions from the aluminium can and the brown glass bottle systems. For instance, CO_2 emissions increased about 13% for 0.5l aluminium cans and about 17% for 0.5l re-fillable glass bottle. Fibre based user packaging, i.e. the six pack board, also had a substantial contribution to the additional growth of the environmental loads of the 0.33l brown glass bottle system. The use of six-packs increased the CO_2 emissions from the system ca. 7%.

After taking into account the credits for recycling and energy recovery the order of the impact potentials of the studied systems changed a little. When the benefits of the material recycling, energy recovery and possible waste heat recovery were given completely to the systems producing these flows, the oxygen depletion potential favoured the 0.33l glass bottle. In the comparisons of 0.5l aluminium can and 0.5l re-fillable PET bottle, all categories were clearly in favour of the PET bottle.

A comparison with the previous study conducted in 1995 indicated that the calculated rates of relevant environmental loads had considerably decreased in each of the studied systems. For example, cumulative CO_2 emissions had decreased 8-12%, SO_2 emissions 20-60% and NO_X emissions 25-35%. Some of the decrease originated at the upgrades of data and methodology. However, there were also other reasons, such as the decreased weights of aluminium cans, increased energy efficiency in glass melting, and increased efficiency of beverage logistics. It was assessed that the emissions per functional units seemed to continue decreasing. New and environmentally more benign solutions were introduced already during the study in all systems.

6 FINDINGS FROM THE CASE PROJECT

The exploration of the interviews and observations from the case project had twofold objectives. The first objective was to answer the previously set research question:

3. How were the goals defined and how were the most important outcomes perceived in the case project?

To answer this question, the goals defined for the case project are presented. Also, the observed or indicated environmental improvement options along with experienced outcomes of the project are discussed. This question is discussed in sub-chapter 6.1.

The second objective of exploring evidence from the case project was to seek insights on interaction and co-operation of actors and companies for LCM. Therefore, data-driven understanding was sought to explain the perceived significance of interaction and co-operation in the case project.

Difficulties in structuring the analysis of the qualitative data were caused by the finding, that the reoccurring themes seemed to be very intertwined. A clear benefit from the case project according to the interviewed actors from the process was the produced LCA study and its results. Also many practical improvements were detected. However, there were also clear discontinuities between the produced LCA results, the realized improvements and the experienced benefits, since there were also disappointments with the outcomes. Some actors were very disappointed in the fact that the expected outcomes were not realized. These were connected especially to the ways that the project was expected to affect the taxation discussions. Despite of these feelings, all of the interviewed participants experienced the process beneficial. Besides the LCA results, their interpretations or practical improvements, there seemed to be other issues affecting the experiences. There were also strong indications of some actors clearly experiencing more benefits in the process than others. These experienced benefits were then not connected to technological changes nor only

to the changes of social processes brought by the project, but also to changes of understanding among the participants.

The experienced benefits were in many cases referred to as increased understanding and learning experiences. Learning is defined, e.g. as a change of behavior, knowledge, skills or emotional reactions (Kuusinen 1995). Many interviewed participants considered the case project process useful or necessary due to the experiences of learning. The participants stated having experienced learning experiences, and these were also implied through observed changes in understanding of environmental considerations and environmentally oriented development practices. Observations therefore also suggested that learning processes occurred during the case project.

An initial overview of the qualitative data then implied, that there are reoccurring themes both concerning the *contents* of learning related to environmental considerations and also the *process* of the learning experiences. Therefore, further questions for the study were:

4. What environmental information was learned in the case project?

5. What were the learning processes like?

and:

6. What was the significance of interaction and co-operation for learning and knowledge creation in the case project?

The information contents of learning are discussed in sub-chapter 6.2 and found features of the learning processes in sub-chapter 6.3. These observations are discussed in the light of previous theoretical sources on learning and knowledge creation, in order to discover the significance of interaction and co-operation in the case project, in sub-chapter 6.4.

6.1 The goals and activities

In this sub-chapter, the definitions of goals and needed activities and perception of useful outcomes from the case project are explored. First, the goals stated in the documentation of the case project are presented. Next, some examples of the environmental improvement options to processes and products found during the case project are presented. Perceptions of the improvements and benefits from the process of the interviewed actors are also discussed, and the perceived outcomes are compared with the goals defined in the documentation of the case project in order to draw conclusions for further study of the case project.

6.1.1 Goals defined in the documentation

The documentation of the case project defines an overall goal for the project to ensure high environmental quality and functionality of the consumer packaging, i.e. to give consumers a proper choice of practical and environmentally sound packaging.

The documentation also states, that a task of the project was to conduct a life cycle assessment of current Finnish beverage packaging systems in order to update a respective study published in 1995. However, to ensure the quality of the LCA study for policy decisions, as well as to ensure the benefits for the participating companies, also a second task was presented. That was to generate and test an organisation and procedures for continuous environmental assessment and improvement of the beverage packaging systems.

The tasks were identified in the project plan as follows:

1 Scientific objective is to update the LCA information on the present Finnish beverage packaging systems from 1995 to 2001-2005 and some relevant future options. This information includes the inventoried total rates of environmental loads, and the results for selected aggregated impact indicators. The results of different beverage packaging systems are compared for impact potentials within functionality groups.

2 To create an organisational scheme for self-maintained LCA information in the brewery product chains, based on the principles of the supply chain management, i.e. on the co-operation of the members of the beverage supply chains. The scheme was an important new methodological aspect of the project, and for example, the scheme will be used as a part of internal environmental management system by the breweries and the retail sector.

The final goal of all stakeholders of the project has been to ensure high environmental quality and functionality of the consumer packaging, i.e. to give consumers a proper choice of practical and environmentally sound packaging.

PARTICIPANTS INTERESTS
Breweries aimed to develop their packaging systems to support the continuous improvement by means of LCA. Retailers aimed to provide practical and environmentally sound packaging for the trade of the brewery products, including recyclable cans and bottles. Packaging manufacturers aimed to provide up-to-date data, including environmental aspects, on their packaging.

ENVIRONMENTAL ADMINISTRATION INTEREST
The Ministry of Environment and the Ministry of Finance of Finland needed up-to-date data on environmental aspects of different products, including packaging. The data from this study can be used, in co-operation with all the stakeholders, to evaluate the possible needs to make changes in the taxation system.

Also, in the documentation of the research process of the case project the intended use of the LCA results was described (Poikkimäki & Virtanen 2003):

> The specific results from the life cycle assessment are used in targeting immediate development and improvement efforts related to products and manufacturing processes. Participating companies use the results on product- and system-specific environmental burdens for informing customers and stakeholder groups. The process and quality of the study also adds the usability of the results in policy processes on different levels, such as environmental taxation, competition legislation and end-of-life planning and regulation.

The tasks emphasize the producing of environmental data and the needed organisation and procedures to produce reliable data also in the future. Although an evident motivation for the research was posed by a threat of changing environmental taxation and related economic interests, estimating the relationship of the economic implications for each operation or company was left strictly outside the project framework.

The specified tasks also included the environmental improvement of processes and products, but the decisions for implementing specific improvement options were left out of the project framework. It was expected that each participating company estimated the options for improvements based on the gained information, as well as the related economic factors. It was then possible to come up with shared improvement efforts among companies as well. Therefore, it was not defined how the acquired data is expected to lead to realized improvements, and neither what kind of improvements were expected.

Due to the common threats to the industry posed by changes in taxation, it was clearly among the expected important outcomes of the project to provide a common forum to discuss the threats and future development directions for the Finnish actors in the beverage industry.

It was also explicitly stated in the documentation, that the case project aimed to build a consensus-based and democratic process. Therefore, the aim was that the decisions taken should be based on a common understanding and common interests served, related to the main goals of environmental data and environmental efficiency development. The aim was that the ways and tones of interaction would differ from "business as usual", i.e. that they should not reflect directly the market situations, size of companies, power relations and economic preferences of the participating companies. Due to the lengthy negotiation process to initiate the project, the goals defined in the documentation of the project seemed to be defined in adequate enough detail, and all participants seemed to be well aware of them.

6.1.2 Found environmental improvement options

During the case project, environmental improvement options were identified in different parts of the beverage packaging life cycles, e.g. in the brewery and retail processes, logistics and end-of-life treatment of wastes. In this sub-chapter, examples of the found improvement options observed by the researcher are presented for further comparison with the perception of the participants in the following sub-chapters.

In the brewery processes, it was discovered, that the usage of lubricants and washing agents can be decreased with adjustments of sprays on the production lines. Also, it was discovered that there are significant differences of energy use in can closure due to different techniques.

With the overall results of the study, it was realized, that a significant amount of energy is used in the cooling of beverages in retail locations. Therefore, plans to reduce the cooling were drawn. The means used were both operational adjustments that could be implemented in a short period of time,

but also the planning criteria of investments in new cooling equipment were adjusted. Also the planning and building of new facilities was therefore affected. Operational adjustments were, e.g. that the temperatures in cooling were adjusted, cooling devices were unplugged or replaced by normal shelf storage in room temperature.

An important aspect in the cooling issue was the competitive situation, where cooling devices were provided by the breweries as an important means of promotion. According to the perception of the breweries and the retail operators, the consumers actually require and prefer cold drinks and the cooling was therefore assumed to increases sales. Discussing the results actually seemed to enable a shared realization of all the parties, that the environmental and also cost loads of cooling are significant and that improvements are therefore needed.

In the light of the produced information, some actors questioned the earlier perceptions on consumer preferences. It was discussed that these will have to be studied further. It was also discovered, that there actually is no exact information on what is "cool enough" in terms of beverage temperature for the consumers, and also, that there is not enough information on what types of packaging are mostly consumed instantly and what will be cooled by the consumers themselves anyway. With the raised awareness and discussions of the operators, it was found, that in many cases the cooling of beer crates of 24 pieces of 0,33l bottles is probably unnecessary, although it was general practice in most supermarket-sized retailers at the time.

The increased information on the environmental and cost loads of the cooling and on the uncertainty of actual consumer preferences motivated the operators for improvements. The operators seemed to not only form an understanding of the needs for improvements, but also a commitment to take action. The shared understanding and commitment seemed to decrease the fear that there will be competitive disadvantage for the first operators to actually start reducing the cooling. Therefore, the role of the co-operation and the processes of sharing information and forming opinions seemed to be very important for realizing these improvements.

Ideas for improving the design of beverage packaging and their secondary packaging were also found. For example, non-recyclable boards used for six-packs of beer could be redesigned to use recyclable board raw-material. Also, it was discovered that the 0,5l brown glass bottle for beer could be redesigned for a better balance in order to decrease the losses on cashier lines and in logistic processes.

Improvement ideas requiring changes in customer behaviour were also found, mainly for increased recycling of materials, such as steel from crown corks and six-pack boards. An improvement option in logistics operations was, for example, the possibility to improve the separation of brewery-specific packaging, which would eliminate additional logistics to exchange packaging between breweries later.

In connection to the project, also options for system-level changes were discussed. There was speculation for possible changes from brewery-operated beverage logistics to retail-operated logistics and also for replacing returnable and refillable PET plastic bottles with crushable bottles and raw-material recycling. These developments would require changes in the processes of many operators in the production chains, affect economic constellations significantly and in some cases also consumer behaviour. Developing these alternatives was not within the framework of the study and thus their possible environmental impact or potential for realizations were not investigated. The comparisons of the current situations with such scenarios were also considered scientifically problematic by the scientific research team due to uncertainties of scenario data.

With the case study, many different types of improvement options were identified. There were operative improvements that could be realized instantly, with no additional cost. Also, there were improvements that would require training or technological changes and investments. There were improvements that would concern only the operations of one company and improvements that would change the operations of several companies and entire chains of operations. Therefore, corresponding to the definitions of environmental improvements, ideas for process changes, product developments and also system-level changes were discovered.

6.1.3 Perceived outcomes, defined goals and found improvement options compared

As stated in the documentation of the project, producing detailed and reliable data on the operations was the primary task. The LCA results describing the potential environmental impacts of the Finnish beverage packaging systems were an undeniably important outcome. Environmental data was perceived as an important result for both development work and for stakeholder communication.

In the case project, the interests to defend arguments connected to the changes of taxation were strong and present in the expectations towards the project for most interviewees. Some participants also pronounced explicitly their interest-based expectations towards the results.

> *"I think we needed arguments and facts for stakeholder discussions. The main goal was actually to produce some data we could use for our external communication… we wanted to have some data showing, that the refillable bottle was more environmental friendly than one-way bottle, point defended by other companies"*

Related to the strong expectations for the results to be used in the policy discussions concerning taxation, one interviewee especially stated a strong feeling of disappointment and mistrust with the project for producing the "wrong" results. Some also pronounced slight feelings of disappointment towards the process, but meanwhile also trust in the reliability and validity of the results.

Many operators stated, that also ensuring and increasing the interaction and co-operation with others was one of the motivations for participation. As a result of the project, some also had realized that they need to increase their interest-based co-operation to affect the developments concerning the industry.

> *" So, the development of our own processes was the main goal, but also a better networking in the supply chain."*
>
> *"Tärkeintä oli olla mukana valtakunnallisessa tutkimuksessa tietääksemme missä mennään. Tärkeää oli myös nähdä antaako tutkimus aihetta muuttaa kierrätyslogistiikkaa."*
>
> *"The most important thing was to participate the national study to know where we are. It was also important to see if the study gives indications for changes in the recycling logistics"*

The interviewees state that not only exact, quantitative data was important for discussing developments and finding improvement targets. Also, for instance, information on the position, opinions, and plans of other actors was considered significant. It is also indicated, that not only the exchange of this information was perceived important, but also the improved understanding of the positions, opinions and plans of others.

> *"After that, the government understands better also the opinion of the retailers"*

Especially the discussions on the possibilities to decrease the cooling of beverages demonstrated that the co-operation in the joint forum created with the study was significant for sharing and interpreting information jointly and generating also shared commitment for actions, internally or in some cases also in-between companies.

> *"If we compare the effectiveness of our equipment against costs of electric power and energy consumption, the demand goes that way and everybody is aware of the need to decrease the consumption of energy."*

It can be concluded, that the primary task to produce quantitative data on the life cycle of beverage packaging stated in the documentation were fulfilled. It should be noted that although the risk from the changing taxation was clearly one of the factors motivating the study, the interviewed participants do not identify many benefits gained related to taxation as outcomes of the process. However, many practical improvements and improvement options were found and also stated by the interviewees. (see also sub-chapters 6.1.2 and 6.1.3)

The created co-operative structures were also clearly beneficial outcomes of the project, since it was perceived important by the participants that the interaction and co-operation increased. These were perceived important for the discussions and generation of environmental improvements. In general it can be noted that although many improvement options brought by the project could be observed, as discussed in the previous chapter, these were not highlighted when the participants were asked what the beneficial outcomes were (see Appendix 1, question 5). The accounted beneficial outcomes were,

however, often related to the interaction and co-operation brought by the project.

The perceptions of the targeted activities and most important outcomes of the project in the interview data therefore indicate that even though interaction and co-operation were not stated as important things as such the project, they were perceived necessary in order to produce the required LCA data. In general, they were perceived to be among the most beneficial outcomes by the participants. The interaction and co-operation were seen to affect considerably the generation of the LCA data and the exchange of other relevant information on environmental considerations. The interaction and co-operation were also implied to enhance the realization of improvements in practice, since in some cases they helped creating shared understanding and also implement improvements, internally in companies or among companies.

Although interaction and co-operation were experienced significant afterwards, they were not seen as goals of intrinsic importance in the planning or beginning phases of the project. The comparisons of the definitions of goals and related activities, found improvements and perceived outcomes therefore indicate that interaction and co-operation were significant for the other two LCM activities, i.e. implementing environmental efficiency improvements and producing and using environmental information. The needs identified within the field of environmental management to elaborate further the understanding of interaction and co-operation processes and their significance are thus also supported by the findings. Moreover, the exploration of the defined goals and related activities as well as the accounts for most beneficial outcomes in the case project support the previous interpretation on the three core activities of LCM.

6.2 Learned information

Nonaka and Takeuchi define information as follows:

> *"information provides a new point of view for interpreting events or objects, which makes visible previously invisible meanings or sheds light on unexpected connections." (Nonaka & Takeuchi 1995)*

An essential quality given to information is novelty and relevance in increasing understanding. (Nonaka & Takeuchi 1995) Although all participating companies needed to collect similar quantitative environmental data on their operations, other types of information were also collected, although not in an organized or a consistent way. Although most of the interviewed actors stated that the information on environmental considerations increased in the process, the experiences seemed to vary a lot and some experienced to have gained much more useful information than others.

In the case project, indications of the following types of information, that were collected or exchanged, could be found:

- information on the shared interests, goals and commitment for the project
- information on what are the phases in the beverage packaging life cycle and who are the representatives of the companies or associations responsible for environmental considerations
- how the product life cycle operates: what kind of processes it entails in general and what companies operate them
- ideas on what is environmental efficiency and how it can be studied
- ideas on what factors may affect environmental efficiency decisions
- data on environmental efficiency and consequent environmental impact potentials of the phases of the product life cycle
- improvement options how environmental efficiency of the product life cycle can be improved
- a preferred level/ planned level of operations according to others
- interests, motivation, intentions and plans of other actors, such as suppliers, competitors, policy makers and NGOs
- shared or conflicting ideas and interests about the development of the product life cycle, e.g. discussions with sub-suppliers or customers to find best practices and strengthened relationships
- strategic importance of some environmental considerations

The information therefore clearly included issues related to environmental impacts and also related to interaction and co-operation to manage these issues. In this sub-chapter, the gained environment-related information is discussed. These are selected based on the interviews, and observations are also used to support interpretations. The analysis therefore includes the assumption that the interviewed operators have pronounced or indicated the types of information they have experienced important.

6.2.1 What is environmental efficiency and how it can be measured

Many interviewees stated to have learned about life cycle assessment and product-based and networked environmental management in general. The interviewees that had been responsible for LCA data collection stated that they learned especially about the measurement and calculation of product-based burdens and the factors affecting the environmental efficiency of processes.

In general, the project increased the understanding of how the potential environmental impacts of products and processes can be studied in the participating companies. Interviews and observations indicated learning on what the environmental efficiency of processes is, and how it can be measured and studied, as inputs and outputs and corresponding environmental impact potentials, e.g.:

"Avoiding losses was not even considered before, and then it is the main benefit."

Some actors had participated in a similar study already in 1995. Therefore, they already had an understanding of the LCA method and its phases. In cases, where the representatives were not the same, or the companies had not participated in the previous study, the LCA data collection demanded more educational efforts. For example, this was the case for the retail companies, where several meetings with both management and operational levels were needed to form an understanding of what data is needed and to start the data collection.

Because of the shared responsibilities of data collection, a general level of a shared understanding of the method and the needed data was necessary. Meetings to explain the method, the needed data and the calculations were organized and they helped forming this understanding. Meetings with retail company and brewery representatives were held, where the processes of each operator were discussed and defined, and questionnaires for data collection were drawn.

It was observed, however, that the LCA method is rather a complicated method and in some cases the understanding form or possibilities could not be shared among all participants. Especially the form and detailed level of data required was not always perceived. In many cases, the data used for standard follow-ups and planning in the companies differed from the data needed for the LCA.

The interviews indicate that the increased understanding of environmental efficiency also supported other continuous development efforts, like environmental and quality management systems. The project also brought understanding and ideas for improvement targets and priorities for many participants. In some companies, environmental training and education activities were connected to the case project and were considered productive.

> *"We also desire to improve waste sorting and treating by training and education in the company. It's a never ending story."*

6.2.2 Needs for process- and product- based data

Generally the participants saw valuable outcomes from the project in the form of detailed, quantitative environmental data describing the environmental efficiency of their processes and products. The assistance and external expertise helped companies to define the relevant parameters that need to be monitored and that are useful for product-based analysis. Many contributions of the process were thus industry- and company- specific.

> *"We learnt how to compare different types of energy use from an economical point of view but also from an environmental one."*

Accurate data based on actual processes and representing the current realities of impact potentials of products enabled the discovering of development options in practice.

"We needed measurements concerning water and energy use, which were provided, and they are the base of improvements."

"..the companies produced the data, so it was much better (than the study done in 1995), and so it increased our understanding. There's always things to be developed. .. the project has, without a doubt, increased the understanding of the participants."

Producing this data was seen elaborate and costly, especially for the companies participating in such studies for the first time. However, it was also realized, that only a detailed enough level of study would bring immediate practical applications as well as an adequate level of reliability for the information to be used for longer term planning and policy decisions. The production systems were studied in full detail, aiming to describe all processes as they are, instead of aggregate processes, for instance. Also the accessories, transport packaging, routes, modes and loads of transportations and many other details were taken into account.

Many participants felt, that understanding on the connections of potential environmental impacts and economic considerations was a valuable output of the process, although it was not always what was expected. It was observed that the collection and processing of the exact data in general seemed to enhance learning on the relationship between the environmental and the economic considerations. This seemed to support integrating the environmental considerations in everyday actions, but also into more strategic questions. Thus, it was indicated, that the gained information supported or guided strategic planning.

"In the future it will guide our development so that we know what are the main areas that we need to develop."

"Before the project, surveys from farming for instance changed our strategic plans, LCA confirmed it."

In some cases the results caused questioning of earlier beliefs on what is environmentally efficient. This new information was considered very important, and therefore could also change strategic plans.

".. the facts and data collected are not strong enough to avoid the fact to change into a recyclable system. So of course, regarding this issue, strategy has to be changed. Moreover, data collection allows us to have knowledge on our weaknesses and work on them."

The collected data was used for corporate social responsibility reports or environmental reports. The participants also expressed commitment to continue the data collection with the learnt procedures. It was observed that some detailed project data was shared in the working groups. That way companies also acquired data from the processes operated by other companies, e.g. their competitors. Data was discussed, checked and verified, but also benchmarked.

"It was a good thing that we worked together with the competitors and these three really ... we could compare and think what is not correct ..."

Significant differences in the environmental efficiency of similar processes were found, raising questions on how the data was produced, but also of the technologies used. For example, there were significant differences in the electricity consumption of retail operations[5]. Also, differences in certain brewery processes were found, such as energy consumption in the can closure process.

Flows of which the economic significance had been considered low were often not monitored on a product-specific or process-specific level. Therefore, with the introduced perspective and collected data, also some significant development needs for future data collection were found.

It was observed, that in some cases the management level participants were not aware of what detailed product- and process- specific material flow data of their operations actually exists or is usable for an LCA study. In some cases, they also seemed to have a different understanding of what data was useful, available, or what the quality of the data was, than the operative level participants from the same company. The participation of the personnel operating the actual processes or collecting the data as well as the scientific team helped the managers understand the true availability and limitations of the data. This occurred also in cases, where additional data variables were needed in order to disaggregate the existing data into smaller, product-specific units to describe the physical realities of processes.

6.2.3 Insights into the interests, motivation, intentions and plans of others

The interviewed actors expressed that they had gained insights into the interests, intentions and plans of other actors in the production network of beverage packaging, also implying that these are relevant information. Especially information on the interests and intentions of policy makers and the future plans shared among other actors were considered important. Some existing information was deepened or confirmed and some new information was gained, e.g.

> *"Breweries had, of course, different opinions than us and it was good that researchers, packaging companies and recycling ones (companies) were between us."*

> *"Nykyinen järjestelmä on vahva ja panimoteollisuudella on vahva lobbaus joka puoltaa sitä."*
> *"The current system is strong and the brewery industry has a strong lobbying defending it."*

> *"But it appears that the authorities don't accord yet enough importance to environmental issues."*

Also, communication of interests and intentions was actively pursued by some industry representatives towards policy representatives.

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[5] The electricity consumption was studied in kWh/m² of store space per litre of beverages delivered, for the LCA calculations.

"After that (project), the government understands better also the opinion of retailers."
".. we hope that the authorities NOW understand how the beverage packaging is affecting the environment. Studies done affected and are nowadays affecting the authorities."

6.2.4 Complexity of environmental assessment and improvement

In general, the detailed level of data requirements for LCA surprised some participants. It was discovered, that producing process- and product- specific data units is most useful for process and product development and environmental reporting. However, many of the participating companies did not produce product- and process- specific data. Especially the disaggregating of data units into smaller ones caused problems in the reliability of the data. The factors needed for disaggregating were often missing or unknown, e.g. when disaggregating production site-based data, for example.

"To be honest, the way it was done was too complicated. They have a lot of questionnaires and excel files and a lot of things they wanted to have in numbers. And I can understand that from a technical engineering point of view. They wanted to have details for all stages separately. But the problem is that we don't have meters. So a lot of the things they were asking, it was frustrating, and we had to estimate to find out consumptions of energy, water, heat etc. So I think now I understand why these were asked but it was a hell of a job to get the numbers and I'm still not sure we got the right ones."

The complexity of the data and the systems caused confusion and frustration also in other cases. The complexity of results was seen as a hindrance also to the applicability of the information.

"We are looking for some tools for the future. LCA is definitely too difficult and produces too complicated data and is not so reliable."

"LCA needs to be improved. It is for the moment too complicated and uncertain."

"There were indeed too much data and the representation is terrible.(in the LCA report) From too different and small areas so we had too much information and we couldn't see the relevant ones. The way the results were presented was definitely too complicated."

It could be observed, that the cause for frustrations was twofold: first, the complexity of data and the quantitative results were experienced frustrating, since flows of materials and energy are measured in a variety of different units (of weight and volume), and also in relation to a variety of impact potentials. Second, the lack of a purely scientific method to interpret the results and the necessity to make value choices caused frustration. Although the LCA procedures were criticised by many interviewees, the source of these problems is not solely, however, the weakness of the used methods. The faced complexities are an inherent quality of environmental considerations, where flows of materials and energy as well as the impact potentials have not only different quantities but also qualities, and their relative significance cannot be assessed without value judgements.

Therefore, the strong reactions of criticism towards LCA reveal that the process and the results of the case project speeded or enhanced the forming of an understanding of the general complexity of environmental considerations and the necessity of value judgements when making decisions. There were statements, suggesting that the decision-making processes concerning environmental improvements were influenced or dominated by economic premises.

> *"Of course (we will make investments for improvements) if our consumers ask for that and if we have the money."*

The frustration appearing in many statements, however, also indicated, that the environmental considerations could have been assigned more weight in the decision-making, if there would have been clearer information on what choices really are the most environmentally friendly ones and how the economic and various environmental values involved can be assessed, especially in the case of conflicting values. Although 5 of the 7 actors interviewed said, that the project has brought benefits to their company in general, and 5 stated, that improvements of environmental efficiency have been found, 5 also doubted or denied an additional value created for the products. The problems in creating added value were most often connected to the difficulties of interpreting the complex results or negotiating conflicting interests.

> *"The lack of information was the most significant barrier (for realizing improvements)"*

Also, for questions if the project affected their own or other people's everyday work or attitudes towards environmental matters only 2 of the 7 interviewed actors gave a positive answer. This indicates a difference in perceiving implementations of improvements and actual changes in attitudes or operations, "everyday work". One possible explanation for this difference is that the constant improvements of processes are, in fact, everyday work for these actors. Therefore it is not identified what improvements are related to the case project specifically. Another possible explanation is that the experienced benefits are other than process adjustments and improvements, and not perceived and identified as environmental improvements, such as the learning experiences. Supporting both of these explanations, the interviewees state improvements of environmental efficiencies of processes, but also state several barriers for their realizations. Along with the actual technological improvements, the increased information and understanding is perceived as an important benefit by many interviewees, and verified by the observations.

There were indications that the process enhanced the understanding of the general complexity of environmental considerations. The complexity of data and the quantitative results caused frustration but also the lack of a purely scientific method to interpret the results and the necessity to make value choices frustrated the participants. The complexity of environmental considerations was also experienced to be a barrier for improvements.

6.2.5 Win-win improvements and connections of environmental and economic considerations

Many participants pronounced that the increased general understanding of the economic and environmental efficiencies and their connections in the production network was one of the most important outcomes of the project. For many participating companies, the study brought new efficiency considerations. Based on the collected information on potential environmental impacts, immediate improvements of production processes could be found. These improvements could also directly improve the economic efficiency of processes.

> *"There is very close correlation in business economy and environmental economy as well. So if we manage to decrease our losses or energy or water consumption and pollute less, it will improve our economic performance, that's for sure."*

> *"It minimizes the costs and in decreasing costs, we decreased environmental impacts as well. We are actually nowadays using less energy. That means less pollution."*

In general, for many companies the project resulted in the discovery of connections between environmental and economic considerations. In some cases also the conflicting environmental and economic values were highlighted. The interviewed operators stated examples where the environmentally most efficient solutions were not economically viable. Some interviewed actors also stated having found the most efficient solutions economically and environmentally, but these were, in their opinion, discouraged by policies.

Although the product- based view was inherent to the project, in the beginning of the project some participants seemed to relate environmental considerations mainly to operational questions connected to issues of emissions or waste management. For some companies, the goals were more attached to verification of previously realized improvements and to backing up drawn strategies for development directions connected to beverage packaging. During the project, when realizing that the results and environmental perspectives would not adequately support these, alternative plans were also made to proceed, with measures external to the project.

Some participants, however, stated that the strategies of their companies were re-evaluated with the deepened understanding of the connections of environmental and economic considerations. For some, the perspective of taking into account environmental considerations thus also seemed to shift from operational questions towards the realization of long-term plans and proactive thinking. Also, with this development the costs of environmental protection could rather be seen as investments, with expected economic returns, rather than an additional cost burden. Therefore the companies could also be more motivated to taking into account environmental factors in strategic development plans.

> *"After the project, we had information based on the environmental effects, which is really important for the next step of the whole strategy of our group."*

The interviews and observations indicate that the found improvements affected the infiltration of environmental considerations for not only operational issues, but also strategic questions. When asked, 6 of the 7 interviewed operators confirmed that the project affected the strategic thinking in the company or their opinion of the key success factors now or in the future.

With the case project, learning experiences on the relationship between environmental and economic considerations were implied and these were also observed. There were indications that the process transformed or re-adjusted environment-related thinking for some participants. Examples of win-win situations were found, and these supported integrating the environmental considerations in everyday actions, but also to into more strategic questions. In some cases also the costs of environmental protection could rather be seen as investments, with expected economic returns, rather than additional cost burdens.

6.2.6 Increased interaction and co-operation

With the extensive participation, interactive relationships were formed among companies and actors in the case project. It could be observed, that in some cases the project also increased the interaction between actors representing different functions or organisational levels in companies through the formal organization of the process, as presented in sub-chapter 5.1. The project created a forum of interaction and co-operation between actors in the production networks, such as suppliers, customers and competitors, and also representing the institutional organizations, such as the Ministry of Environment and the Finnish Technology Development Fund, TEKES. Also, stakeholders, such as environmental NGO's and independent experts were involved in the expert follow-up group and the critical panel. Also other structures for co-operation were observed among the participating actors that were formed around similar interests or personal relationships.

Many operators stated that the project increased their dialogue and interaction with other companies, authorities or stakeholders in the production network. Four of the 7 interviewed actors answered directly yes, when asked if they had built new ways of co-operation with their stakeholders during the research process.

> *"Yes. I think that the companies that have taken part, that there are better discussions between the companies and also with the companies and authorities. With the Ministry of Environment, Ministry of Trade and Industry and Ministry of Finance. Yes, co-operation in beverage packaging project was bringing first of all better discussions between companies and then with authorities."*

> *"You can say so. There is a new structure for managing the recovery of packaging."*

There were also other indications of an increased co-operation and it could be, in fact, suspected that most interviewed operators had experienced this. However, some interview answers indicated that the term stakeholder was in

fact, understood as parties external to the production network altogether, or parties not in direct connection with the company. Therefore, the definition of stakeholder would not include e.g. suppliers and customers that the companies have a direct relationship with. This differs from the common definition of stakeholders, e.g. as "any group or individual who can affect or is affected by the achievement of the organization's objectives" (Freeman 1984). In addition, for some actors in the production network the definition of "us" in general, in contrast to "them", would not refer to the company specifically, but the company and its actively co-operating parties. Therefore it was suspected that the increased co-operation may, in fact, have also changed the perceived boundary of "us" as an interest group and "them" as clearly external stakeholders, with differing interests.

The interviews indicated that also future plans to develop dialogue, co-operation and partnerships were made. In general, indications of interaction and co-operation being increased within companies and among companies were confirmed.

6.2.7 Risks and barriers from interaction and co-operation

There were significant indications both from the observations and the interviews that factors connected to the interaction and co-operation were experienced not only enabling or supporting the development process but also threatening it.

There was a common agreement on the goals and related activities of the project and measures were taken to verify the reliability of the LCA results and their proper publishing. However, there were problems of trust, some tension in interactions and even conflicts. Building a consensus-based and democratic process was aimed at, as discussed in sub-chapter 5.1. Efforts were made to focus on environmental considerations in the discussions. Both the scientific and the practical co-ordination of the study were conducted by neutral parties, aiming to serve equally all participants of the project. Also, the chairmen of the steering group and the working groups were maintaining positive interaction despite of occasional disagreements.

Despite of these efforts, however, some participants expressed mistrust in the scientific quality of the study. For example, some NGO representatives doubted the quality of some specific calculations in the critical panel, since the calculations could not be fully transparent and they had no possibility to redo them. Also, some actors strongly resented the fact that their preferred scenario calculations were not included in the final results of the study, despite of the fact that these were not within the main goals that were agreed upon by the steering group of the study. In addition, after the project it was observed, that some industry representatives presented interest-based interpretations of the results in the media. This was contrary to previous agreements and caused conflicts.

In the interviews, all mentioned barriers for realizing environmental improvements were connected to the understanding, attitudes and actions of actors. Four actors stressed the role of information and an understanding of what changes are needed and why. The answers imply that these are internal barriers within production networks. The attitude towards environmental considerations was mentioned twice. Also, external barriers like the attitudes of the whole society and of policy actors were mentioned. Despite of the fact, that finding the resources for environmental improvements was given as an example of a barrier in the interview, it was not confirmed once. It is possible, that the emphasis is on the barriers connected to interaction, since the conflicting interests were strongly present in the project. Therefore the barriers connected to the interaction are possibly perceived, mentioned and given attention to due to the strong feelings generated by the interest-based debates.

In general, the conflicting interests and problems of trust among the involved actors threatened severely advances in the case project. The outlined formal organization and deadlines acted as common routines that supported the process. Also, the roles of the co-ordinators and chairmen, as stated earlier, were observed vital since they helped keeping the process going and overcome the feelings of mistrust and complaints expressed by some.

6.2.8 Necessity and benefits from interaction and co-operation

Many interviewees stated as an important outcome of the case project the realization that co-operation can be very beneficial. An important discovery for many participants was that many of the found environmental improvements benefit several companies in the network instead of just one.

The idea that co-operation concerning environmental issues in the production network can be beneficial was also seen as a strategically important realization. Increasing co-operation was also seen as a strategic development option for the whole industry.

> *"I think we should need some changes in attitudes, both on suppliers and customers, our strategic partners. To take those key questions on the table and find solutions together. I think much too much today is done so that our suppliers and customers and us are doing their solutions to these problems, so why don't we make that as strategic partnerships. There could be real win-win situations for everyone. We have started to discuss these teams. It's much easier to see what I am getting out of that than what we are getting out of that. So you have to share to have win-win situations."*

These realizations can be explained through a change of perspective. That the life cycle perspective could in some cases change the perceived importance of needed improvements and also the perceived benefits of the improvements. As a result, improvements could be targeted in co-operation to find most cost-efficient ones, both in the environmental and the economic sense.

Therefore, the understanding of improvement options available for companies was in some cases extended not only by information on the improvement options concerning their own processes, but also with

information on the range of possible improvement options elsewhere in the production networks.

A brewery representative states, that the project supported the development of co-operation with the retailers, for example, since it caused a re-evaluation of using old cooling devices in retail shops. Although the cooling devices were provided by breweries as part of the promotion of beverages, the electricity consumption costs were carried by the retailers. After realizing both the economic and environmental burdens of the cooling, operating the cooling process as usual was not in the interests of neither the retailers nor the breweries.

> *"Also, (we have started) to see where are the "crooks" in the chain and have some kind of system where we have to have investments etc. to use the money the most effective way in the whole supply chain."*

The "crooks in the chain" are interpreted as referring to the processes that have most significant environmental and perhaps also economic burdens, rather than to actors or companies. With the understanding of the benefits of the life cycle perspective, this quote also demonstrates the generation of some level of common responsibility. The idea of this common responsibility and its implications was also discussed within the case project.

In some meetings, it was discussed that the end products carried the environmental, economic or image burden of all actions in the production network. With joint discussions and projects, a holistic picture of a life cycle could be created and many actors could take responsibility of improvements. Correspondingly, also the benefits from the development work could be jointly discussed and shared. A conclusion shared by many operators was that often the success of products benefits the whole chain. A clear outcome expected by many was an increased environmental and also economic efficiency in the chain. Also the benefit of being proactive in preparing for future taxation and its possible market effects was mentioned.

The qualitative data suggests that the co-operation in the production network enabled or enhanced the perception that finding possibilities for economic benefit and also competitive advantages is possible or even probable by LCM activities seeking environmental improvements with joint development in the production network.

6.2.9 Feelings generated by the process and the results

Expressions implicating strong feelings generated by the case project are typical in the interviews.

> *" … it was frustrating…"*
> *" .. ja siksi olimme niin pettyneitä." ("and that is why we were so disappointed")*
> *".. I was much more confident in the results."*
> *".. we were much more confident afterwards."*
> *" So I was a little disapponted and my main feeling was frustration."*

"People in our company are disppointed and don't really understand why authorities act that way."

Many expressions of disappointment and frustration but also strong feelings of increased motivation for environmental work were observed during the project. The experiences of frustration and disappointment are conflicting with the observed positive outcomes of the case project, such as practical improvements and learning experiences, and with the positive feelings of motivation and increased confidence. Some of these strong feelings are related to the differing and conflicting interests of actors and companies, but the interests do not, however fully explain these experiences.

It was also noted in the observations that some actors participating in the data collection efforts developed and expressed a genuine interest towards the studied issues. Also, some management level participants were noted to express genuine environmental interests, despite of the related economic considerations. Actors were observed being content when improvement options were found. Also reactions of frustration and anger were observed. However, it is suspected that the negative reactions were not so openly revealed in social situations and therefore they were less often observed.

There were also observations noting feelings of surprise, especially with some findings in the initial results of the study. In some cases the amount of efforts needed for data collection was also a negative surprise for the participants. The finding that the cooling of beverages at the retailers causes both economically and environmentally very significant burdens was found surprising. Also the considerable burdens caused by the six-pack boards were considered surprising.

Thus, the feelings were suspected to be often related to changes of understanding and seem to be a special characteristic to the experiences from the case project. Both the positive and negative emotional reactions seem to be strongly related to the experiences of understanding and also related to co-operative processes seeking environmental improvements.

6.3 Features of learning and knowledge creation

A wide variety of theoretical insights into organizational learning, learning organizations, interorganizational learning and knowledge creation can be found (see e.g. Halme 2001, Easterby-Smith 1997). The notions of learning processes on the individual level, on the organizational level and in networks differ (Easterby-Smith 1997). Indications of learning on many levels could be found in the case project. In this sub-chapter, learning processes related to the interaction and co-operation of actors and companies in the case project are discussed, according to the studied focus.

Learning processes occurring in interactive situations have also been studied with a variety of perspectives, e.g. as interactions between experts and novices, as collective influences in solving cognitive conflicts and as collective knowledge construction processes. Consequently, also the views on the central processes and important outcomes of these processes have been found to vary. (Häkkinen & Arvaja 1999.) Häkkinen and Arvaja (1999) state that processes of collaborative learning consist of intertwined features of dynamic cognitive, emotional and motivation increasing processes. Since collaborative learning is a complex and dynamic process and related theoretical insights are various, the discussion here starts with the identified significant features of the learning processes in the data-driven findings.

Four important features in the learning processes that occurred in the case project are identified: the collective nature of learning, the continuity of learning through the repetition of efforts and the experiential nature of learning. Also, it was observed that the learning was in many cases deeper than mere acquisition of information, i.e. construction of knowledge. The features describing the contents and features of learning processes and related theoretical perspectives are discussed. They are then expected to enlighten the significance of interaction and co-operation in LCM activities.

6.3.1 Collective learning

The main focus of this research is on processes shared among actors and companies. Although individual traits can have significant effects on learning processes, also the roles of dialogue and interaction in learning have been stressed (see Easterby-Smith 1997). Especially the constructionist views have emphasized, that learning is a product of a community rather than of the individuals in it, and therefore it cannot be transferred from one setting to another (Easterby-Smith 1997). The importance of participation in a community of learners for learning has also been emphasized by e.g. Lave & Wenger (1991). The collective nature of the learning experiences was explicitly expressed by an interviewed participant:

> *"I was lucky, because I learnt a lot from the others."*

Halme (2001) has demonstrated that the actual learning processes in the network can be more important than the network structure. It was observed that in the case project the organization formed a specific context for the learning experiences. The building and design of the co-operative process seemed important since they created a context differing from "business-as-usual". (see sub-chapter 5.1)

The efforts required cross-functional and cross-organizational participation of actors. Also, the co-ordinators and chairmen of meetings took personal responsibility to act as mediators in cases of conflicts. There were regularly set meetings to compare, make iterations and verify the quality of the collected LCA data and the efficiency of the process. Therefore, the organization

of the project enabled – or in some cases even forced - the interaction of operators in a context specific to the project.

Häkkinen and Arvaja (1999) define as an important feature of collaborative learning that the outcomes of the learning processes are more than the sum of outcomes that could be created by the participating individuals alone. The knowledge creation theory also includes similar assumptions, since it emphasizes the interaction between individuals as a precondition and a platform for processes where knowledge can be created (Nonaka 1994, Nonaka & Takeuchi 1995, Nonaka & Konno 1998).

In the acquired information contents, the insights into the interests, motivation, intentions and plans of others demonstrate that these learning experiences were enabled by and closely related to the collaboration. However, it could also be observed that acquiring and understanding the other information required collective efforts. Understanding what is environmental efficiency and how it is studied, forming a holistic picture of the environmental considerations related to product life cycles, and drawing plans and readjustments of operations and strategic considerations could not have been realized as individual efforts. Exchanges of information among different types of information and of various actors and of various companies in the production chains were thus required to collect this information. As stated earlier, it was also found that some actors actively pursued this communication of interests and intentions in the network (see sub-chapters 6.2.3, 6.2.8).

Argyris and Schön (1996) describe organizations both as communities that act as holders of knowledge but also as representations of knowledge. They also suggest that in some situations organizational knowledge can be bigger than the sum of the knowledge of the individuals in it. The findings suggest that also temporary organizations, like the one in the case project, can act such a way. The co-operation in the case project created a temporary community around the product life cycle that was exchanging the knowledge that the members hold, but also creating new environment-related understanding.

It is estimated that based on the case project findings an evaluation whether the structure or the learning process was more important cannot be made. On the contrary, these two seemed intertwined. The organization and created context of interactions and co-operation seem important since they enabled or enhanced the collective learning processes. Therefore it can be concluded that interaction and co-operation were crucial for learning on environmental considerations.

6.3.2 Continuous learning

A continuity of the learning efforts could be observed, through the repetition of efforts both with successive projects and within the case project individually. It was also stated in the documentation that the project aimed at continuous development rather than one-time efforts.

Since some companies and actors had participated in a study already in 1995, there was a continuity of development from the earlier project in 1995 to the one in 2000, as stated in an interview:

> *"Between the two projects, a lot of improvements were done."*

However, many examples indicated learning experiences related to the case project specifically, e.g.:

> *"The management process has changed, in small steps, water and energy consumptions are known better, as well as losses."*

Many phases within the case project were also repeated in order to achieve the required results. It is difficult to separate what learning specifically is connected to the case project and what to other practices of continuous development, since these are intertwined.

The continuity of learning processes resulting from the repetition of efforts was, however, identified as an important feature affecting the outcomes and experiences of the case project. It was observed that the learning was deeper, since there was time, and also a necessity in many cases, to process the issues more thoroughly and at several interactive situations. The benefits of repetition of development efforts has been emphasized e.g. in the application of environmental management systems (see ISO 14001). Argyris (1983) has also stated that repeated studies are more likely to support a more profound type of learning. These notions will be further discussed in sub- chapter 6.3.4.

6.3.3 Learning from experience

The active participation and interaction of actors was cross-functional and cross-organisational. The participants also needed to participate actively in the planning of the process, the LCA data collection, verification and interpretation of results.

As stated by Collin (2005), there is no need to distinguish learning and doing as separate activities. She suggests that although workplace learning has often been seen as either *knowledge acquisition* or *participation*, both individual agency and social life are important aspects of learning and there are constant interrelations between them. She therefore prefers to see learning as a holistic entity, consisting of intertwined individual and social processes of learning and doing. Eteläpelto (1998) also states that practical experience should not only be seen as a related or affecting variable to professional expertise, but is actually an essential component in it. Moreover, according to her findings the functional role of professionals in an organization largely determines the nature and quality of their expertise. These notions explain the discovered importance of active participation of many individuals. The duties allocated to the participants then seemed significant for enhancing learning and contributing to building their environmental expertise.

There were also internal and external motivations for the participation and finalization of the project as planned. Commitment was built among the participants to co-operate until the set goals would be reached. There were also pressures to finalize the results due to the political process of revising the taxation for beverage packaging. Therefore reliable LCA results were needed and required as an outcome of the process. For this purpose, active participation of actors in planning, data collection and verification and in interpretation of results was required. The participants also stated, however, that they participated actively in order to develop their own understanding or to develop their manufacturing processes.

Argyris and Schön (1996) see that organizational knowledge is embedded in routines and practices and also in physical objects. Individuals act as holders of knowledge and also employ and decode it in their activities - although they would be unable to put it into words. The active participation required in the case project and the requirements also to interact with other operators and companies in some cases provided practical experiences of what can be the environmental considerations within the context of their own businesses and the product life cycle. Thus, these theoretical insights support the notion that active participation and gained practical experiences were important for learning and building of professional expertise for many of the participants.

6.3.4 Creating knowledge

There were indications, that the case project enhanced the motivation for environmental considerations. The motivation, in many cases was generated by the belief, that there is a connection between economic and environmental considerations, as discussed previously. Some interviewed operators also experienced changes in strategic thinking.

These indicate that the case project not only brought new information to the participating actors, but also, that this information possibly affected their actions taken by the participants and the made decisions in the participating companies. Some actors first increased their capabilities to solve simpler problems connected to environmental issues, but they also increased their capabilities to question practices and reflect on strategic issues from an environmental perspective. Thus there were indications on deeper learning experiences, corresponding to the concept of double-loop learning.

Argyris (1983) defines double-loop learning as a type of learning that requires re-examining the underlying problem, or that occurs when mismatches in organizational variables are corrected by first examining and altering the governing variables and then the actions. Also, it has been defined as learning that results in a change in the values of theory-in-use, as well as in its strategies and assumptions. (Argyris & Schön 1996.)

Since it was stated by the participants that the strategic thinking of many operators seemed to be affected by the process, the findings indicate, that a detailed study of the relationship of environmental and economic considerations in current operations and consequent learning can also be useful

for long-term thinking and strategic decision-making. Halme (1997) suggests that the shift from a traditional management culture to an environmental management culture requires unlearning of certain old assumptions and customs that exclude environmental considerations from decision-making and learning new ones that include the environment in the underlying value system of management. An internal or external trigger for change is therefore needed to initiate this development, and unlearning of old knowledge and assumptions and learning new ones will need to take place. The case project suggests that in some cases such developments took place and also resulted in practical changes in the respective companies.

Despite of the outcomes of the LCA data and results, found improvement options and possible political influence of the project, some actors expressed disappointment and frustration towards the outcomes and conclusions. However, all interviewed actors indicated learning experiences that were significant. The strong feelings connected to the learning processes seemed to indicate, in fact, a specific trait of the learning process. (see sub-chapter 6.2.9)

The feelings indicate that many participants seemed to form ways of relating to the acquired information on a personal level. Therefore, it was concluded that the learning was deeper than mere adopting of new information. It could be described as *forming an understanding on the environmental considerations in the specific context of individual work of the actors and the company.* This observed deeper type of learning can also be interpreted as a process of *knowledge creation* (see Nonaka & Takeuchi 1995).

Kalla (2003) sees organizational learning and knowledge creation as boundary concepts and meeting point for multidisciplinary subjects. She sees them overlapping in many functions and processes that they cover. In fact, the knowledge creation theory (see Nonaka & Takeuchi 1995) includes references to all of the other, previously discussed features in the learning process. The theory of knowledge creation is considered useful in understanding the learning process of the case project. Therefore, the case project is further analysed in the light of the knowledge creation theory in order to discover if creation of knowledge actually took place and to discuss further the significance of interaction and co-operation.

Nonaka and Takeuchi define information as a flow of messages that enables the creation of knowledge, when anchored to beliefs and commitment of its holder. Knowledge, in turn, differs from information in the sense, that it is not only related to meaning, but also to beliefs, commitment and action. (Nonaka & Takeuchi 1995.)

Relating to beliefs, commitment and action, the concept of *knowledge* corresponds to the previous finding of an *understanding* that was generated in the case project. The theory on knowledge creation by Nonaka and Takeuchi is based on an assumption, that individuals and organizations not only process information when they innovate, to solve existing problems and adapt to changing environments. It is assumed, that they also actively create new knowledge and information, to redefine both their problems and solutions. Therefore, with the process of creating knowledge, organisations have a

potential to re-create their environment. (Nonaka 1994, Nonaka & Takeuchi 1995.)

The assumption of individuals' and organisations' ability to *create* knowledge instead of merely processing information explains the necessity of relating to the information on a personal level in order to form an understanding of it. The active role of individuals and organisations in creating knowledge, to adapt to changing environments and to affect them also explains the observed double-loop learning (see Argyris 1983) and the outcomes that are actually capable of transforming operations (see Halme 2001).

Knowledge can be individual or shared and collective (Nonaka & Konno 1998). Also, knowledge can be tacit or explicit, i.e. personal, context-specific and hard to formalize and communicate, or codified in formal and systematic language (Polanyi 1966, as cited by Nonaka & Takeuchi 1995). According to Nonaka & Takeuchi, knowledge is created by the exchanges of tacit and explicit knowledge, in a social process between individuals. They identify four modes of knowledge conversion, where this can occur. These are socialization, externalization, combination and internalization. (Nonaka & Takeuchi 1995.) The possible realization of these phases in the case project is discussed further in the following sub-chapters.

6.3.4.1 Socialization of knowledge

In the first phases of the case project, information on the interests of actors was shared. Joint interests were sought and goals and commitment for the project were drawn. According to Nonaka & Takeuchi (1995), organisational knowledge creation begins with a socialization mode, building a field for interaction of tacit and explicit knowledge and with a dialogue between actors. They also state, that without some kind of shared experience, and associated emotions, it is extremely difficult for a person to project her- or himself into other individuals' thinking process. The resulting forms of created knowledge can therefore be called sympathized knowledge.

In the case project, there was a shared experience of the threats posed by the planned changes in taxation, which motivated a joint effort. Among the parties negotiating the participation in the project, an understanding was formed on the most useful or possible ways of carrying out the project and on the orientation of the actors. The scientific co-ordinators had developed ideas of a shared, networked LCA project. A commitment of the actors to a joint effort was generated with several successive meetings and negotiations, i.e. there was a socialization of the tacit ideas why the project would be beneficial and how it could be carried out. Due to competitive situations in the market and resulting tensions between the actors, there were many hindrances for establishing a joint project. However, three important factors that supported the socialization of a joint effort and project plans were identified. First, the common threats posed by planned changes of the taxation of beverage packaging, and second, the goal definitions based on environmental considerations supported the establishment of the project. As a third factor, there was the design of the project, with a cross-

functional and cross-organizational participation as well as the co-ordinators and chairmen that acted as mediators supporting positive interaction and socialization. (see sub-chapter 5.1)

The conditions of the case project can be compared to the concept of *Ba*, a foundation for knowledge creation outlined by Nonaka and Konno (1998). The main goals of the case project were about increasing individual and collective knowledge, which process the Ba is defined to serve. To participate in the Ba means to get involved and transcend one's own limited perspective or boundary (Nonaka and Konno 1998). In the case project, the actors needed to transcend the perspective of their individual position in the company they work for, and enter the perspective of the product life cycle and the common interests. In the socialization of knowledge, the direct encounter between individuals is stated important. Therefore, the aims to create a specific context to the case project that would emphasize the life cycle perspective and differ from the "business-as-usual" (see sub-chapter 5.1), served the socialization of the ideas.

During the project, some questions were observed to cause discussions in several successive meetings, with sometimes no apparent progress in reaching consensus. As an example, the calculation for defining the refilling rate of the brown 0,33l beer bottle was debated in 3 successive meetings of thesteering group. The refilling rate being an important calculation factor for the environmental efficiency of the bottle life cycle, the retail and brewery representatives were perhaps hoping to affect the results. Despite of the detailed verifications and explanations by the scientific research team of the reliability of the calculations, no overall acceptance on this factor was formed. Since the responsibility for the scientific reliability of the study was on the scientific team, this disagreement did not hinder the project from advancing.

The scientific quality of the study was estimated high by many participants and members of the critical panel. The interviews as well as the documentation of the project, however, demonstrated conflicting views among the actors, expressing both trust and mistrust in the scientific quality of the results. It can also be suspected, that even though there may have been a successful socialization process for all the participants to share the understanding of the calculations and rely on their validity on the individual level, it was not expressed in an explicit form, due to the companies interests involved.

It was observed that during the project the participants exchanged many types of tacit knowledge, e.g. on the realization of the project and on possible development directions of the entire industry, and that common ideas of profitable development directions were also formed among some of the participants. Socialization of understanding could be observed not only in the beginning of the project, but also later on in the process.

6.3.4.2 Externalization of knowledge

After the initial negotiation phases of the case project, the tacit knowledge on the process of the case project and the orientation and commitment of the actors

to a joint effort were turned into an explicit form. These were several versions of a project plan, funding applications and finally legal agreements, where the goals and responsibilities of actors were defined. Also a model for the process of the project was defined in the plans. This phase in the case project corresponds to the definition of the externalization mode of information, defined as a process of articulating tacit knowledge into explicit concepts, with resulting outputs of conceptual knowledge. (Nonaka & Takeuchi 1995.)

Two conditions for externalization are identified. The first one is that there are expressions of ideas or images as words, concepts, figurative language and visuals. Therefore, forms of functional dialogue are often needed. Second, another condition for externalization is a translation of the tacit knowledge into explicit, easily understandable forms. (Nonaka & Konno 1998.) After the initiating phases of the case project, initial flow sheets of the operations in the production networks were drawn. The flow sheet made an explicit representation of what are the phases in the life cycle, what kind of processes it entails and who operates them. Also, questionnaires were drawn to collect the needed data for each industry and life cycle phase specifically. The actors responsible for the data collection were explained the method and specific procedures by the scientific team. With questionnaires for data collection, the variables measuring and representing the environmental efficiency of specific processes and of the entire life cycle were introduced in an explicit form.

In the interaction of the companies, the actors could also discuss the operations in the life cycle of the packaging in practice. Information on how the product life cycle operates, and what affects decisions concerning the operations was shared. Therefore, the two conditions needed for externalization were fulfilled.

In the externalization phase selecting people with the right mix of specific knowledge and capabilities for a project team, a taskforce or a cross-functional team is stated important (Nonaka & Konno 1998). In the case project, the scientific team and the co-ordinators brought additional knowledge on the definitions and study of environmental efficiency into the project framework. In some cases also the understanding of the participating companies on these issues was extended on a more general level.

It was observed, that the participation of both management and operative level actors was significant for generating practical applications. The socialization for the understanding and development of environmental efficiency of the actors may explain why many improvements were found, although they were not always the expected ones. It has also previously been discovered, that LCA studies can lead to organizational outcomes and to environmental improvements that are not necessarily the anticipated ones. Therefore it has been stated that LCAs can be seen as providers for experiences for learning rather than support for specific decisions (Baumann 1998).

6.3.4.3 Combination of knowledge

Combination is identified as the third mode of knowledge conversion, referring to a process of combining different bodies of existing knowledge, and producing systemic knowledge (Nonaka & Takeuchi 1995). There are three identified processes. First, new explicit knowledge can be captured from inside or outside a company. Second, the knowledge can be disseminated for example through presentations or meetings. Third, justification is needed in order to reach agreements and practical actions based on the acquired knowledge. In the combination of knowledge, the shared platform can be a virtual one, and created through on-line networks, documentation and databases. (Nonaka & Konno 1998.)

In the case project, combination of knowledge occurred first in the initiating phases of the project, when the project plans were viewed and revised to conform to the expectations of the participating organisations. Also, combination occurred when the plans for data collection were drawn by the management committee to involve participants representing other organisational levels. Knowledge of the recommendable procedures for the project of the scientific co-ordinators was combined with the knowledge of company actors on current business operations and on actors who would be able to deliver or collect the needed data, and also with the knowledge on the information needs of the policy representatives.

With the socialization, also dissemination and justification processes occurred in the successive meetings in the initiating phases of the project, since the project plans were drawn and contracts were signed.

With the results, combination could be observed in the cases when the data on environmental efficiency was viewed in the light of economic efficiency, win-win improvements were found and processes were adjusted or development plans were drawn to do so (see sub-chapter 6.1.2). Combination also occurred when the strategic implications of the produced environmental information were compared to the existing strategic plans (see sub-chapter 6.2.5).

Traits of processes of knowledge combination for capturing and integrating new explicit knowledge, for disseminating the knowledge and also for justification of it can be found in the case project. Moreover, traits of these can be found in many phases of the project.

6.3.4.4 Internalization of knowledge

The fourth mode of knowledge conversion is called internalization, meaning that explicit knowledge, like shared mental models or technical know-how, is internalized into an individuals' tacit knowledge base. Nonaka & Takeuchi (1995) state, that internalization can be enhanced by the verbalization of knowledge into documents, manuals or oral stories. Internalization produces learning by doing and operational knowledge.

The conditions given to internalization are first, embodying the explicit knowledge into action and practice, and second, mobilizing the knowledge by using simulations or experiments. Mobilizing can mean continued exercises that stress certain patterns and working out such patterns, for example training with senior mentors and colleagues. (Nonaka & Konno 1998.)

With the efforts to collect LCA data, the study and understanding of the environmental efficiency were taken into practical actions. With the iterative phases to assess and validate the data, in some cases similar procedures were also repeated several times. In the case of some brewery processes, there were searches of additional data, measurements and benchmarking of similar processes. The experiences of the participants were either satisfying, in cases, where new information brought improvement options that could be realized immediately, or frustrating with the detailed or complex information and results (see sub-chapters 6.2.5, 6.2.8 and 6.2.9).

Despite of the negative or positive nature of the experiences, all interviewed participants implied directly or indirectly, that they had learned new things and new ways of thinking. New ways of thinking that were operationalized by the project were life cycle thinking and the idea of the profitability of a joint development of a product life cycle, as well as the connection and relevance of environmental considerations for businesses (see sub-chapter 6.2.5). The indications that these considerations also affected strategic considerations suggest, that the environmental considerations were not taken to practice only on an operational level, but also concerning more strategic issues. This indicates that the knowledge was employed also for strategic thinking.

Since most of the participating companies were not followed for a longer time period after the project, it cannot be discussed how many of these strategic notions were mobilized also in practice. Some, however, were indeed carried further. As an example, in a retail chain the considerations from the case project concerning the cooling of beverages lead to renewed guidelines for building new retail facilities. As stated by an interviewed actor, in the planning of new facilities, cooling spaces for beverages have been considerably reduced, which has also been a factor reducing the overall electricity consumption.

In any case, many different types of exchanges among actors both internally in the participating companies and among actors from different companies were observed and the qualitative data on the interviews and on observations demonstrate learning experiences where knowledge was internalized by individuals.

6.3.4.5 Conclusions on knowledge creation

The knowledge creation theory provides an enlightening explanation for the findings in the qualitative data. The theory explains why the project was experienced useful, despite of conflicts of interest, frustration and disappointments with the calculation results or the possible political influence.

There were extensive participation of actors, interaction and co-operation and experiences of learning.

The exchanges of information, the interaction and the consequent knowledge creation occurred not only among the representatives of one company, but also among many companies simultaneously or collectively, within the co-operative forum of the case project. The interaction and co-operation were also threatened by conflicting interests and consequent risks were experienced. However, a co-operative forum, an extensive cross-organisational and cross-functional participation, mediators striving to keep the interaction positive, and the obligation to view the environmental considerations from the product life cycle perspective helped creating a specific space or platform for knowledge creation. The co-operative forum involved many significant operators in the beverage production network, increasing the interaction of companies, scientists, experts and also some NGOs.

The case project increased the understanding of actors on the study, measurement and development of environmental efficiency, but also about the interests and intentions of other actors and companies and the connections of environmental and economic considerations in general. Learning brought positive experiences, although there were also strong feelings of frustration and disappointment. It was found, that the generation of strong feelings signs for processes where the actors formed ways to relate to the acquired information on a personal level, and thus for a knowledge creation process. All four modes of knowledge creation presented by Nonaka and Takeuchi (1995), i.e. socialization, externalization, combination and internalization of knowledge could be found in the case project. A knowledge creation process and exchanges of tacit and explicit knowledge thereby explain why the process generated strong feelings and the participants seemed to form ways of relating to the acquired information on a personal level. These processes enlighten why the case project provided experiences of learning and supported the building of professional environmental expertise for many participants.

However, the modes of knowledge creation did not correspond to the phases of the process. In some phases of the case project, several different modes were observed. Examples of the found indications of the observed modes of knowledge conversion are presented in Figure 11.

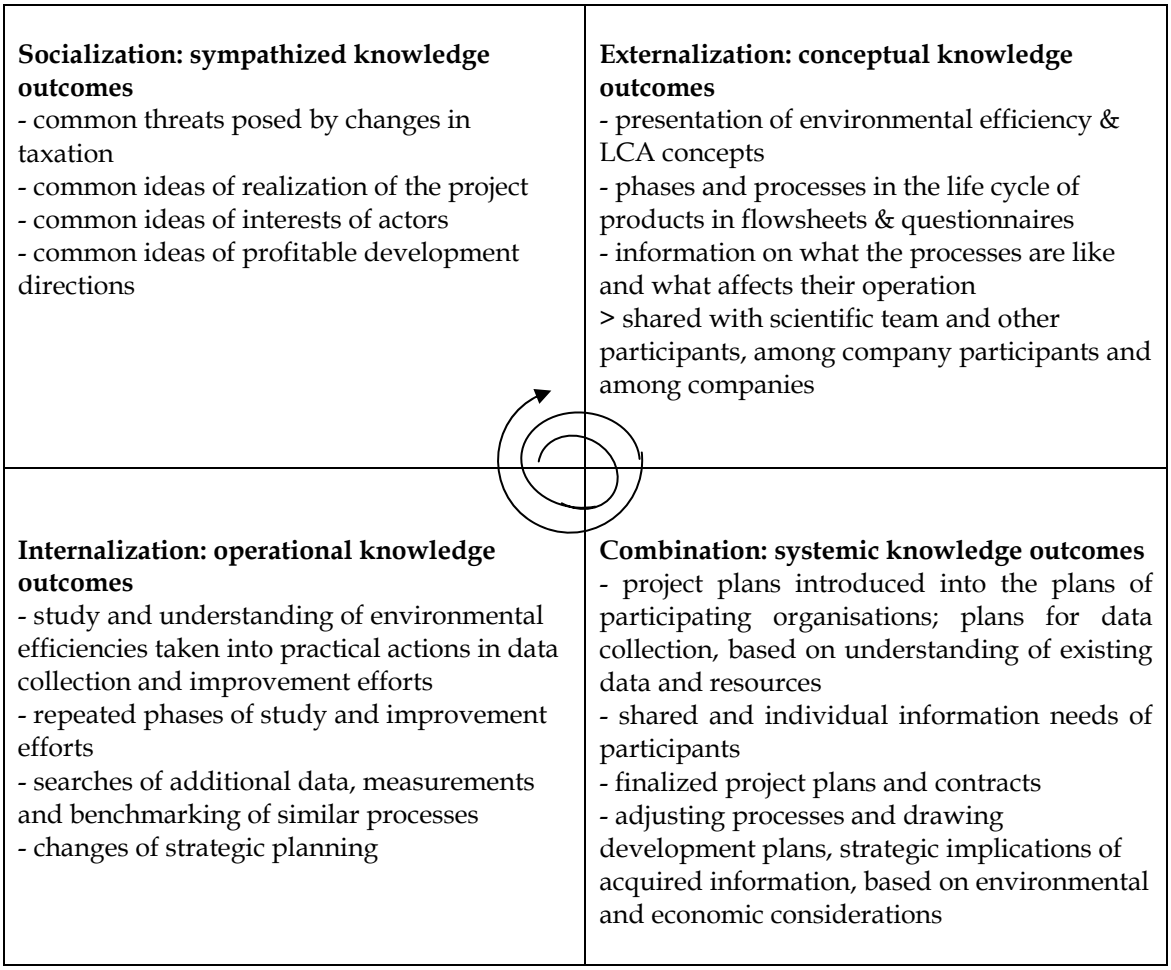

FIGURE 11 Indications of the four modes of knowledge conversion in the case project

6.4 Significance of interaction and co-operation for learning and knowledge creation

In general, the identified features of the learning process align with earlier insights on learning at work. Collin (2005) identifies four features necessary for understanding learning at work:

- to see learning and work practices intertwined and the goal of practice itself usually bypassing learning as such, and learning at work as informal, incidental and practice-bound
- to note the importance of individuals' prior experiences for work and for learning through it and for individuals' conceptions of how they interpret their experiences in different contexts, situations and their individual goals
- to note that the larger work context, i.e. tasks, team, organization, culture, determine learning in the workplace
- to note that learning is social and shared, but not wholly benign or conflict-free

The findings of this research also strongly indicate the practice-bound nature of learning experiences. Especially the effects of a "closer look", i.e. the activities of collecting detailed data and information on the production processes of the network seemed to contribute to the finding of win-win improvements and to creating knowledge on the relationships between environmental and economic connections.

In the findings of this research the importance of individuals' conceptions and prior experiences can also be suspected, although individual processes were not the focus of this research. For instance, the interviewed experts' experiences vary significantly in some cases. All of the interviewed participants experienced the process useful or necessary and some significant outcomes were stated, i.e. environmental improvements or even changes of strategic thinking. There were, however, also indications of some disappointments with the outcomes.

The significance of the context, differing from "business as usual", in enhancing or even enabling the learning experiences was also discovered. Also, the collective nature of the learning experiences was verified, through identifying many exchanges among individuals and different types of information in the knowledge creation process. In addition, a continuity of the learning processes was identified. According to Collin (2005), learning and utilizing experience is a continuous process. Therefore, the findings of this research align with the ones by Collin (2005) also in relation to the continuity of the learning process.

The strong feelings of disappointment and mistrust testify that the shared learning processes are indeed not wholly benign or conflict-free. These feelings, however, when connected to the learned contents, were found to signal for processes where the participants actually related to the acquired information on a personal level, and therefore also signal for environmental knowledge creation.

The discovered features of collective, continual and experiential learning in the interactions between individuals and companies, as well as the strong feelings generated in the process were discovered to be also features connected to the four modes of knowledge creation processes. These features also correspond to learning at work as defined by Collin (2005).

Based on the findings in the interviews and observations, learning at work and creation of knowledge were central themes describing the experiences of beneficial outcomes from the case project. In this chapter, learning at work and environmental knowledge creation are discussed further to understand the significance of interaction and co-operation in processes seeking environmental improvements.

Two inter-related notions for the significance of interaction and co-operation for learning and environmental improvement are identified. First, the interaction and co-operation enhanced learning, in some cases even enabled it. Second, through the learning on environmental issues they also helped overcoming barriers of development and motivating environmental work. An

overall conclusion of the interpretations can be made that interaction and co-operation enhanced improvement and innovativeness outcomes. Based on the visible changes as well as accounted learning experiences and increased understanding, it was also suspected that the process had effects on the organizational cultures of some of the participating organizations.

6.4.1 Enabling and enhancing learning and knowledge creation, building professional expertise

Based on her review of concepts, Kalla (2003) states that organizational learning and knowledge creation both require interaction and communication of people. Previous studies indicate that relationships also in industrial networks are defined to a large extent by social relations. These are important for enabling interaction between individuals and creating mutual trust and confidence. In addition to social relations, participating practical organising activities across company boundaries has been found significant for learning in industrial networks. (Håkansson & Snehota 1995.)

The importance of the social interactions or routines related to the case project were that they provided the necessary platforms for knowledge creation, the ”Ba” (Nonaka & Konno 1998), or social context and shared activity for learning (see e.g. Collin 2005, Lave & Wenger 1991). The interaction and co-operation of actors and companies were necessary for realizing the four modes of knowledge creation and therefore they can be seen as necessary preconditions for learning and creation of environmental knowledge in the case project. Through these interactions and their organization, the case project also provided a specific context of the product life cycle and of a focus on environmental considerations. The experience of active participation and interactions with others in the case project can be seen central for enabling and enhancing learning and knowledge creation.

As discussed in the previous sub-chapter, there were indications that on the individual level some actors experienced the environmental knowledge creation more than others. A useful feature in the built environmental expertise was that in many cases it could be employed also after the project, or in areas not identified within the application focus of the case project. Examples of this are the cases where the gained knowledge was employed for sustainability reporting or strategic partnership building.

Eteläpelto (1998) finds that professional knowledge and expertise are first and foremost determined by subjects’ functional roles in their work communities and a specific context. The context may consist of the working organizations with their working cultures, but also of external factors such as clients and markets that are important determinants of the professionals’ functional roles. She concludes that experience should not be seen as a separate element but an inherent part of professional expertise. The context-specific nature of learning has also been emphasized by many constructionist views (Easterby-Smith 1997). The accounted significant learning experiences can also be interpreted as building of an environmental expertise that some participants

benefited from. The active role of these participants in the case project as well as the specific context and interactions formed by the project enabled the building of professional environmental expertise.

The findings suggest that in the case project active participation and social interactions were closely connected to learning and knowledge creation on environmental considerations. They also enabled the realization of the four modes of knowledge creation and an active role for the participants in the context of their working environment as creators of environmental knowledge (Nonaka & Takeuchi 1995). The active participation, interaction and an extension of knowledge context for the participants and practical experiences and therefore contributed to building professional environmental expertise among the participants.

6.4.2 Possible effects on organizational cultures

Halme (1997) outlines that changes of organizational cultures towards more environmentally benign behaviour involve learning and creation of new knowledge. Lave & Wenger (1991) see the increased ability to participate in a community of learners as an important outcome of learning. The importance of participation stems from the meanings produced by the culture of the community and the ability of learning and learners to both learn in that specific context and also transform those meanings (Lave & Wenger 1991). In the case project, there were several examples of such processes where new meanings were collectively created, e.g. shared understanding of environmental considerations and interpretations of environmental efficiency or of the most urgent development needs in the manufacturing networks (see sub-chapters 6.1.2 and 6.2).

Argyris and Schön (1996) also describe systems of belief within organizations as "more or less constant meshing of individuals' images of their activity in the context of their collective interaction." Changes of belief in the case project were, for example, cases where understanding of environmental considerations within the working context of each company and the production network were created, and the connections between environmental and economic considerations were learned (see sub-chapters 6.2.1 and 6.2.5).

Also Brown and Duguid (2001b.) note that learning does not only involve acquiring facts about the world, but it also involves acquiring abilities to act in the world in socially recognized ways. Learning involves acquiring identities that reflect both how a learner sees the world and how the world sees the learner. What individuals learn always and inevitably reflects the social context in which they learn and which they put it into practice (Brown and Duguid 2001b.). Thus, the outcomes of learning are both changes of understanding and changes of actions in the respective social context. Therefore significant individual and collective learning processes also affect the social contexts, and can also affect practical operations.

Although differences of the learning experiences among the participating actors in the case project could be suspected, all of the interviewed participants accounted for learning experiences. Also many practical changes of operations of even strategies were accounted for or observed. Moreover, changes of perception were observed. Halme (1997) states that collectivity and approaches where organizational members work together horizontally and vertically may assist generating commitment and capacity for innovation, thereby also supporting the observed fact that the cross-functional and cross-organizational co-operation in the case project supported learning.

Halme (1997) states further that in order for an environmentally benign cultural change to proceed, it is essential that in the period when old and new ways of doing things compete, the organization gains positive experience from the environmentally improved actions. She also states that changes towards environmental organizational cultures require unlearning certain old assumptions and customs that exclude environmental considerations from business decision-making. She describes the unlearning as a turbulent process that also involves conflicts.

The qualitative data from the case project indicates that there were many experiences of useful outcomes, and learning motivated further environmental work. These motivational factors will be discussed further in the next sub-chapter. There were also indications that this did not take place without conflicts arising, as indicated by the strong feelings of disappointment and mistrust appearing in the interviews. According to observations, conflicts were arising between prior and new understanding, and also between individuals and companies, due to interests or opinions. Changes of thinking and perception on environmental and economic considerations and their connections were expressed and also changes of activities were observed.

The findings suggest that the collective learning and knowledge creation processes related to the case project may also have affected the organizational cultures of some of the participating companies. The quality of the used qualitative data does not, however, allow a further exploration of the possible changes on the level of each or any of the organizations in more detail. The individual companies and their development are also not the main focus of this research.

6.4.3 Overcoming barriers and motivating for environmental work

Based on the findings in the case project, interactive and co-operative processes enabled or enhanced learning and knowledge creation. Learning processes, in turn, were observed significant in seeking environmental improvements and innovativeness, since they helped overcoming the most important barriers of improvement and motivating for environmental work.

It was discovered that a basic knowledge of all operators on what is environmental efficiency and how it can be measured and calculated cannot yet be assumed in the production networks. Therefore it is not surprising that the experienced, most significant barriers for environmental improvements stated

in the interviews were connected to the understanding of environmental considerations and the attitudes of actors and institutions. Consequently, increasing environmental knowledge creation helped overcome these barriers, as also the actual, reached improvements suggest.

Various economic motivations for network co-operation have been presented. Supplier actions or views of stakeholders can cause severe environmental risks to firms and risk management has been an important motivation for supplier and stakeholder co-operation around environmental considerations. (see for example Hall 2001, Young & Kielkiewicz-Young 2001, Handfield et al. 2005.) Also other benefits for co-operative or partnership approaches have been called, e.g. sharing data and knowledge, solving problems, enhancing innovations and seeking competitive advantages. (De Bakker & Nijhof 2002, Boons & Berends 2001, Gunningham & Sinclair 2002, Green & Hunton-Clarke 2003, James et al. 2002, Juniper & Moore 2002, Young & Kielkiewicz-Young 2001.)

Dealing with the risks posed by the changes in taxation of beverage packaging was clearly one of the most important motivations for the participation of companies in the case project. However, many other experiences motivating environmental work appeared in the interviews and observations. Most importantly, realizations that environmental work can be worthwhile also from the economic perspective seemed to motivate a proactive attitude in environmental considerations.

For many participants, the win-win hypothesis (see Porter & van der Linde 1996) was confirmed when improvement options were found that benefit both the environment and the economy. (see sub-chapter 6.2.5) By providing examples, the project seemed to make explicit that there is, in fact, a connection between the environmental and economic perspectives, and in the cases of win-win improvements even a correlation can be found in some cases. When discussing the win-win rhetoric, Cairncross (1996) argues, that although "going green" cannot be economic to all companies at all times, looking for possibilities of win-win situations should not be too short sighted or too operational, but should account for creative thinking and longer perspectives in time. Therefore, the found examples of win-win opportunities are significant not only from the environmental perspective but also as motivational factors.

In the case project there were realizations that co-operation or even joint commitment of actors is beneficial or even necessary (see sub-chapter 6.2.8), and in some cases joint commitment was also formed for the realization of improvements. The realizations that the success of products benefits the whole production network increased motivation for co-operation and environmental work. These realizations correspond to earlier evidence that the market performance of a company is not only dependent on the functioning of its own operations, but also the functioning of its relationships to others (Håkansson & Snehota 1995). Thus, understanding the importance of developing business relationships can be a significant outcome also in the context of environmental management.

Rintanen (2005) divides motivational factors driving environmental management into ethical motives and profit-oriented motives. The observed motivational increases discussed above are strongly related to profit-oriented motives, such as the eco-efficiency of activities and the environmental imprint on corporate and brand image. She connects ethical motives with values and the processes where values are espoused and used within a culture of an organization. Following the logic that the greener the organizational culture is, the greener the organizational behaviour also is, she concludes that ethical motives are a prerequisite for greening of corporate culture, which in turn enhances proactive environmental behaviour. Indications were found that the understanding brought by the case project may have affected the organizational cultures of some of the participating companies. Moreover, the interviewed actors state that the process also brought proactive thinking and behaviour, for environmental considerations and related co-operation. However, based on the collected evidence it cannot be further explored weather these changes were purely based on profit-oriented motives or if ethical motives were employed more after the changes.

In any case the interviewed actors experienced the process important and useful, despite of the fact that they assessed the economic resources allocated to the project larger than the economic benefits. Many also directly stated their commitment to continue environmentally oriented development work and the intrinsic importance of environmental considerations in their own activities. Therefore, the presence of ethical motives was also observed and they also affected the process and interaction and co-operation of actors.

For many of the interviewed and observed actors, the process of the case project enhanced the understanding and considering environmental factors in practical activities. In general, it can be concluded that the interaction and co-operation and consequent learning and knowledge creation in some cases helped overcome the barriers related to understanding environmental considerations and also motivated for environmental work. It should be noted, however, that the acquired environmental information and motivation do not only refer to environmental data and environmental improvement, but also to other information, such as e.g. economic interests. Therefore, it can be suspected that an increased environmental knowledge contributed not only to the making of more environmentally efficient decisions and solutions, but also to purely economic ones. Therefore it was not clear that the process would have increased the ethical motivation of actors and companies and consideration of environmental factors.

6.4.4 Enhancing innovativeness and environmental improvements

Collin (2005) concludes that the goal of learning at work is to cope better with the surrounding environment and to develop at work. She presents a view according to which learning is a transaction between the individual and his/her environment in which both the individual and the environment develop all the time. Individual and social change processes enable the individual to manage

better in his or her environment and therefore learning also involves a constant change of the reality around us in which we as individuals take part by (re)constituting it. (Collin 2005.) Also Argyris and Schön (1996) describe that double-loop learning results in exploring not only the objective facts surrounding an instance of inefficiency, but also the reasons and motives behind those facts. These notions aid the interpretation of the case project experiences.

Learning in the case project context seemed to extend the perception for some participants and companies by introducing or enforcing the presence of environmental considerations in business decision-making and operations. Also, learning seemed to extend the perception towards an increased understanding of the significance of environmental considerations among other operators in the production chain or among the stakeholders. Therefore it can be concluded that with the context and process of the case project, environmental considerations were introduced or enforced as an additional dimension of thought for the participants.

Brown and Duguid (2001a.) conclude that the source of innovation lies on the interface between an organization and its environment, and that an innovative company not only interacts actively with its environment and reformulates internally but also is active in reformulating the environment:

> *"Alternative world views, then, do not lie in the laboratory or strategic planning office alone, condemning everyone else in the organization to submit a unitary culture. Alternatives are inevitably distributed throughout all the different communities that make up the organization. For it is the organizations' communities, at all levels, who are in contact with the environment and involved in interpretive sense making, congruence finding, and adapting. It is from any site of such interactions that new insights can be co produced."(Brown & Duguid 2001a.)*

According to this view there is innovation potential on all organizational levels and therefore also the active participation, learning and environmental knowledge creation processes on all of these levels are important, if environmental innovation is pursued. The participation of operators of different backgrounds and tasks and consequent different perspectives, as well as necessary combinations of resources among companies have also been seen beneficial for the generation of innovations by Miettinen et al. (1999). The reason is that there is a knowledge base in a network formed by companies that can be activated and used when needed. The development of competence then takes place to a large degree in those network relationships (Håkansson & Snehota 1995).

The importance of the context, the structure and the active participation created for the project for reaching and experiencing beneficial outcomes can be understood through the inter-connectedness of learning and doing on many organizational levels and among organizations. The "doing" activities in practice were collection of LCA data and other information, and development of operations, and were therefore also related to environmental innovation activities.

As indicated, the actors attributed an intrinsic value to the learning and knowledge creation experiences. Therefore, the creation of knowledge increased the experienced usefulness of the LCM exercise, even though the more tangible outcomes did not always satisfy the participants. In some cases the interactive learning processes also enabled the building or negotiating of a shared commitment to realize improvements in practice. This was evident, for instance, in the case of reducing the cooling of beverages (see sub-chapter 6.1.2).

de Bruijn and Tukker (2002) note the importance of learning for the generation of environmental innovations. Nonaka and Takeuchi (1995) outline the significance of knowledge creation as a resource enhancing continuous innovation and therefore leading to competitive advantage. The findings of the case project indicate that learning and interaction processes were important in creating the outcomes of environmental improvements – and also for the outcomes of knowledge and expertise to be used for development in the future.

The importance of active participation for beneficial outcomes has also been noted by de Bruijn and Hofman (2002), who state that in order to move beyond the one time impact of a pollution prevention project, and for companies to use pollution prevention as a concept for environmental management and organisation, it is necessary for companies to enter into a learning process. Therefore companies have to invest significant time in the project and should not play a passive role (de Bruijn & Hofman 2002).

The co-operation of organisations can be manifested through common administrative routines and systems, aiming at a more efficient use of resources. Similarly, the know-how and tacit knowledge of a company reflects not only the knowledge of its personnel but also that of other companies and organisations to which it is connected through business relationships. Therefore it has been suggested that technological development is facilitated or constrained not only by those with whom the company maintains direct relationship but also by the technology of other third parties. (Håkansson & Snehota 1995.) The experiences that the case project increased possibilities for environmental improvements, economic benefit or competitive advantages also indicate the mobilization of a wider competence-base, due to joint actions.

The findings indicate that the personal, active participation of a wide range of operators was significant for learning and environmental knowledge creation in the case project. The practices of producing environment-related information, learning, knowledge creation and consequent innovativeness producing environmental improvements seem tightly intertwined. Interaction and co-operation were therefore significant in the process of companies interacting with their operational environments and adjusting accordingly, i.e. through activities producing environmental improvements and innovativeness.

7 CONCLUSIONS

The goal of LCM and the related activities in the definitions

The definitions of LCM outline an overall goal for LCM to improve the environmental efficiency of product life cycles so that they will be more sustainable. The found three core activities are producing and using environment-related information, implementing environmental improvements and interaction and co-operation. Life cycle assessments are often seen as the most important tools of LCM, and efforts have much focused on issues of data and quantitative calculation procedures.

The definitions of environmental improvements appearing in environmental management literature are in many cases overlapping. Therefore, a clear distinction cannot be made on their effects on the material and energy flows of a production network, or the types of innovations they imply. Environmental improvements in production networks operating product life cycles can be seen as technological changes that change the flows of materials and energy in the processes along the life cycle. The changes have a system boundary of effect, meaning that the changes touch a range of processes and operators. The system boundary of changes is generally wider than that of a single process where the change originates.

The focus of activities seeking environmental improvements can therefore shift from the outputs of processes or the life cycle towards the inputs and the products and functions served by the product or service concepts. Direct continuums from incremental to radical and from process to product development can not be assumed, since there are processes of technological discontinuities in-between the different levels of innovations. (de Bruijn & Tukker 2002) Therefore, LCM can produce both incremental and radical process and product innovations. De Bruijn and Tukker (2002) see both incremental and radical innovations as step-by-step developments. Since system-level changes cannot be planned in a deterministic manner, continuous learning in the process of change is crucial (de Bruijn & Tukker 2002).

In any case, needs for developing and applying more radical changes and a longer time horizon have been stated by many researchers. (Rennings 2000, de Bruijn & Tukker 2002, Stevels 1997.) These types of more fundamental changes of industrial systems are suspected to change entire techno-economic paradigms and bring significant environmental efficiency improvements and redesigns of entire industrial systems (Freeman & Perez 1988, de Bruijn & Tukker 2002). Stevels (1997) defines the time scales for sustainability improvements for products being up to 30 years. Rennings (2000) states, that there are needs for improvements, which would combine sustainability with changes of techno-economic paradigms and outlines the time frame for these changes, saying that "it is realistic to assume time scales of half a century or more for major changes in important economic and social sub-systems". Therefore, there are two factors emphasizing parallel development of optimizations in current production systems while radically more sustainable solutions are being developed. First, in the intertwined processes of incremental and radical innovation, the continuous learning through development practices for optimizations can significantly support the development of the more radical changes in the long-term. Second, the expected time perspective of developing sustainable solutions emphasizes needs to seek optimizations of current systems in order to prevent further environmental destruction.

The system boundary of environmental improvements affects the availability and validity of environmental information describing them. Different types of information may be needed and available and therefore also different types of measures for producing and using information may be needed. Also, different types of interaction and co-operation among actors and companies may be needed for using and producing information, but also for realizing the improvements in practice.

The interpretations of LCM definitions seem to support the notions of Rickhardsson and Welford (1997) stating that corporate environmental management has a strong focus seeing technology as means to pursue continuous growth. The LCM definitions stress the activity of implementing environmental improvements, thereby highlighting the possibilities brought by technological changes. Research is therefore needed on the potential or importance of the processes of interaction and co-operation affecting these developments. Also considering environmental improvements in a product life cycle as different types of innovations strongly implies, that interaction and co-operation are needed both within and in-between companies. The interpretative concept research therefore strongly implies needs to understand the role of interaction and co-operation in LCM practices. These were studied further with qualitative data from a case project.

The definition of goals and perception of most important outcomes in the case project

The case project provided the companies with detailed and reliable LCA data on beverage packaging, to be used for development work and for stakeholder

communication. However, interest-based expectations on the effects of the results in the discussions on taxation were failed in some cases. The case project also produced many practical environmental improvements that were observed and accounted for.

The comparison of the goal definitions and perceived outcomes in the case project shows that even though the interaction and co-operation were not set as goals for the case project, they were often identified among the most important outcomes with intrinsic importance. The other results of the processes were perhaps not always the expected ones. For instance, the calculation results were not supporting the preferred packaging as much as expected or the project did not have the expected effect on the taxation decisions. However, due to learning experiences, the outcomes as a whole were considered useful and necessary by all of the interviewed operators.

Learned information, features of learning and significance of interaction and co-operation in the case project

In the case project, learning on many environmental considerations was observed, such as the definition and study of environmental efficiency, complexity of environmental assessment and improvement, and connections between environmental and economic considerations. The participants also experienced learning on environment-related interaction and co-operation between actors and companies.

The previously mentioned barriers for environmental co-operation include competitive situations, conflicting interests and problems of trust (Young & Kielkewicz-Young 2001). Indications of the presence of all of these barriers were detected in the case project. The interaction and co-operation were also experienced to cause significant risks for the LCM process. The findings therefore suggest, supporting earlier notions, that co-operative processes may present considerable challenges for production networks. However, in the case project the interaction and co-operation were also discovered necessary and significant for the exchange of information and for the creation of environmental knowledge, and for the realization of environmental improvements in practice.

In the case project, the learning processes were observed collective, continuous and based on practical experiences. Also, a deeper learning than mere acquisition of new information was observed. The actors not only acquired or processed many types of environment- related information, including detailed LCA data, but also formed ways of relating to the information on a personal level and regarding to the specific context of their own work. Therefore, they were active creators of environmental knowledge in interaction and co-operation with other actors. As a result of the interactive processes, increased understanding on the relationship between environmental and economic considerations was formed and also shared in some cases. That understanding could be employed not only for immediate practical

improvements, but also for looking further towards future strategies and strategic co-operation to be developed.

Even though the organization of active cross-functional and cross-organizational participation required extensive resources, the interaction and co-operation were significant. They not only enabled learning and knowledge creation, but also enabled building of professional environmental expertise for some actors. Moreover, they helped overcome the experienced barriers for development, connected to understanding, and motivated for environmental work. They also enhanced innovativeness and enabled finding many improvement options along the product life cycles. Some improvements were considered mutually beneficial among the companies in the life cycle. In some cases there were indications that the case project may also have affected the organizational cultures of the participating companies.

The data-driven exploration and discussion of the findings in the light of theoretical sources support the idea that active, personal participation and co-operation of a wide range of operators were significant for learning, knowledge creation and innovativeness in the case project. Based on the other studies on learning at work and on environmental improvement, the findings of the features of learning processes in the case project seem quite general ones. Also, due to their links to innovation activities the findings may bear some implications regarding the activities of LCM. The findings may also contribute to the development of corporate environmental management. These implications are therefore discussed further in the following sub-chapters. These implications are seen as conceptual interpretations aided by the experiences from a case project, and are presented as suggestions to be discussed further, since their generality and applicability for other cases cannot be further tested with the qualitative data collected here.

7.1 LCM activities as elements of environmental innovation

From the perspective of learning, many current researchers see knowledge and practice inseparable (see e.g. Brown & Duguid 2001a., Brown & Duguid 20011b. Collin 2005, Lave & Wenger 1991). Also in the case project, active participation, learning and knowledge creation were found to be strongly interlinked.

Learning has also been defined as the bridge between working and innovation (Brown & Duguid 1991a.). The importance of learning in processes seeking environmental improvements or innovations has also previously been called by several researchers in the field (see e.g. de Bruijn & Tukker 2002, Halme 2001, Carnegie et al. 2000, Sage 2000, Vickers et al. 1999).

The LCM activities of producing and using environment-related information, practices of interaction and co-operation as well as practices of seeking and realizing environmental improvements were strongly interlinked in the case project. Furthermore, experiences of learning and knowledge

creation related to the connections between these activities seemed to provide an explanation for the experienced usefulness of the case project, despite of the fact that the outcomes were not always the expected ones.

In the case project, the environmental knowledge creation process held an important role in generating an understanding on the relationships of the environmental and the economic, and in finding and realizing environmental improvements. The knowledge creation process required active participation of actors in the information collection and improvement efforts, i.e. interactions and co-operation. It was found that the participation and knowledge creation also enhanced environmental innovation in many cases.

Consequently, the connections between interaction and co-operation, using and producing environmental information and environmental improvements seemed to enable the environmental knowledge creation and enhanced innovativeness brought by the project. In the case project, the three core activities could therefore be seen as elements connected to learning and environmental knowledge creation. Moreover, the connections of these elements seemed essential for producing environmental innovations, as presented in Figure 12.

Producing and using environmental information from the life cycle perspective is enabled and enhanced through interaction and co-operation. Therefore, an extended context for understanding the connections between environmental and economic considerations in the product life cycle can be created.

Environment-related information, in turn, serves finding practical improvements and further motivates processes seeking environmental improvements. The improvement activities can then also be discussed and in some cases also co-ordinated in the production networks. These intertwined activities then form a specific context and activities for knowledge creation and consequent innovativeness.

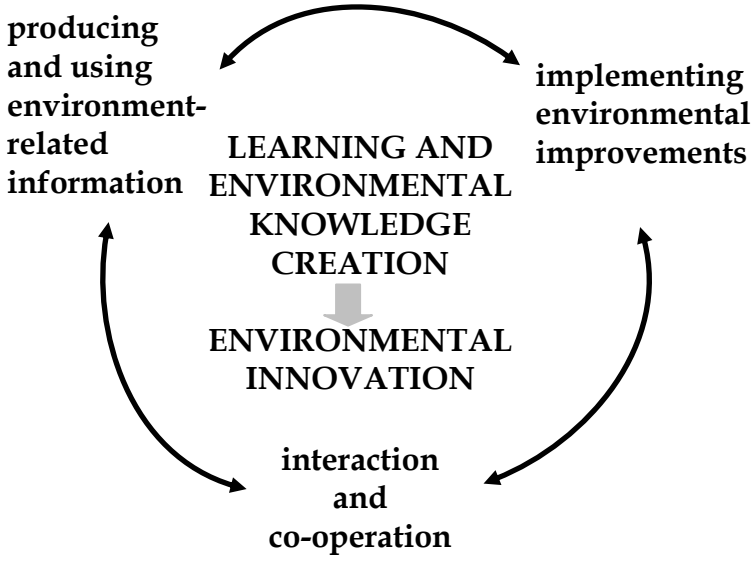

FIGURE 12 The three activities of LCM, connected by learning and environmental knowledge creation, as elements producing environmental innovation

Based on this conceptualisation, the role assigned to technological solutions in the development towards sustainability is not highlighted over the other LCM activities. Also innovations of social processes, such as organization of business operations and innovations regarding the ways of collecting, producing and using environmental information are included within the definition of environmental innovations. Therefore the case project findings support the views of Rickhardsson and Welford (1997) that the technology-based focus may hold back development of businesses towards more sustainable solutions. de Bruijn and Tukker (2002) see incremental and radical innovations as step-by-step developments. They also stress the need for continuous learning along the processes of change, since system innovations cannot be planned in a deterministic manner. Also Brown and Duguid (2001a.) see learning as a focal issue for innovativeness, where learning at the daily activities is in the other end of activities and radical innovations created in the laboratories in the other.

Like in the case project, the outcomes of the project were not always the expected ones, but nevertheless they were considered beneficial for future development and in some cases also business strategies. It is therefore concluded that for the research of LCM practices, a focus concentrating on technologies and quantitative data may not reveal the full importance of interaction and co-operation, or related learning and knowledge creation processes.

7.2 LCM for dynamic and interactive corporate environmental management

Life cycle assessment is seen as the most important tool for LCM and for assessment of environmental impacts of product life cycles in general. As demonstrated by recent studies on LCA practices, many European LCA projects have lacked outputs of practical applications (Frankl & Rubik 2000, Loikkanen et al. 1999). However, in the case project a detailed enough level of study and LCA data, learning and environmental knowledge creation experiences were seen beneficial – also in bringing immediate practical applications as well as information and understanding to be used for longer term planning, strategic considerations and policy considerations. The case project produced several improvements and improvement options. The findings suggest that one of the reasons for previous problems to find practical applications from LCAs may be the lacking of sufficient, active participation for the realization of interaction and co-operation among actors, and consequent lacking in learning and knowledge creation experiences to enhance innovativeness and ideas for improvements.

As Heiskanen (2000b.) has argued, LCA can lead to both confusion and enlightment among managers. In her study, the enlightment seemed more prevalent than confusion. Heiskanen (Heiskanen et al. 1995) also argues, along

with Welford (1995) and Baumann (1998), that LCA can be seen as a device for structuring information and directing attention and action, rather than a decision-making tool. The findings of this research support this view. Despite of the expressions of frustration and confusion connected to the complexity of environmental information, beneficial learning and increased understanding on environment-related issues were experienced. Therefore, the findings here suggest also that for reaching experiences of enlightment from any LCA practices, whether related to other LCM efforts or not, a more detailed and context-specific management and establishment of the interaction and co-operation processes can be useful.

The participants of the case project experienced useful outcomes from the process, especially through learning and environmental knowledge creation. Also some opportunities for improving business operations were found. In the case project working to discover and deal with environmental considerations was experienced useful in the economic context. Improvements and improvement options were found and in some cases also strategic thinking was affected. The findings thereby rather demonstrate the significance of understanding the relationship between environmental and economic considerations for business decisions, instead of portraying environmental issues only as sources for business opportunities (Esty & Porter 1998, Porter & Van der Linde 1996) or as sources of threats and additional costs (Walley & Whitehead 1996).

The case project findings strongly support the notion that environment-related knowledge is beneficial in the development of products. In her case studies concerning the development of environmental management, Rintanen (2005) found that the studied meat industry companies did not regard environmental management as a source of competitive advantage. Also, she found that cost efficiency was linked to the development of environmental improvements and the environmental quality of products depended on the price level that consumers accept. Creative and innovative actions were seen to contain major risks of failing. However, contrary to her findings on the risks of innovativeness, the findings here suggest that innovative actions were rather seen as significant opportunities. Learning and environmental knowledge creation in the project motivated developments, through an increased understanding of the possibilities and also through practical improvements. Increased understanding provided ideas and also means to reduce environment-related risks through an improved understanding of the interests and plans of other actors affecting the development of the industry.

The holistic and detailed picture of the environmental impacts of production processes built with the participation in the project provided learning cases for the participants. The actors learned that all activities have some environmental impacts. In many cases, also the understanding on how the economic outcomes of operations are affected by environmental issues was increased. This understanding was employed when ideas for improvements were found, improvements were realized and plans were drawn for further

actions. The findings therefore indicate that in some cases learning and knowledge creation can also enable decoupling the costs of production and environmental quality, i.e. help increasing environmental quality of products without necessarily increasing the costs. Also the definitions of LCM imply that these types of clean production outcomes or more radical innovations can result from LCM. Therefore, the findings suggest that environmental quality does not directly depend on the price level that consumers accept, but rather on the level on environmental knowledge and expertise, and perhaps also the culture within or among companies.

The discovered ideas for improvements also suggest that there is environmental innovation potential all over the manufacturing network. Rintanen (2005) states that in her case companies, creativity and innovation were left to companies specialized in environmental solutions and services. In the light of the findings here, it can be suspected that this would imply that a large part of the environmental innovation potential in the networks would not be perceived at all. Her conclusions imply also that the interviewed managers considered that many environmental considerations and solutions may be left to other operators. Therefore it is implied that these challenges are not perceived as possibilities for building environmental expertise.

It may also be possible that some of the case project participants faced the challenges unwillingly, despite of the motivations stated for participating. In the interviews, however, the interviewed operators all testified experiences of learning during the case project. The increased understanding related to environmental considerations was experienced beneficial in the work context. Although also significant differences in the learning processes were observed, an interpretation was made that the case project built the environmental expertise of some participants. Considering also the accounted economic possibilities or benefits and found strategic inputs, the challenges of the case project can be significant for the participating companies in some cases.

According to the conclusions of Rintanen (2005), systematic environmental management is a license to operate, but too strong exposure of environmental issues is seen as a potential for competitive disadvantage. On the contrary, the findings here indicate that the created knowledge was seen to support long term economic and strategic considerations, through an increased understanding how environmental considerations do affect or can affect economic profitability of operations and products and vice versa. This knowledge was naturally not only used for the development of environmental efficiencies, but also related to economic interests.

The findings of this study imply that after the case project many of the interviewed operators did not perceive environmentally oriented and other business development as two clearly separate issues or practices. The understanding of their connections and intertwined nature was increased, although it was clear that they could not always be combined. This understanding was not solely created by the case project, but learning and

knowledge creation in the case project also contributed to the development of such a perception.

Learning and environmental knowledge creation processes affecting the building of professional expertise of the actors and possibly also organizational cultures of the companies may therefore explain the possible differences in perception between the statements studied here and the companies studied by Rintanen (2005), and their differing conclusions on the relationship and possibilities of innovation and corporate environmental management. A study on the use of LCAs in two Swedish companies also suggests that there are considerable differences in the ways that individual people react to environmental challenges - and thus also in the ways how environmentally oriented development procedures are carried out in companies (Rex & Baumann 2005).

As a whole, for the practices of corporate environmental management, the case project findings imply that there can be a strong continuity of efforts between the levels of impact identification and management and strategic considerations. When set in the framework of corporate environmental management, learning and knowledge creation enabled developing a continual improvement spiral of environmental efficiency (as outlined by the ISO14001 standard) for the product life cycle perspective. The spiral results in an interaction between the three levels of corporate environmental management, as described by Pesonen (2003). This idea is presented in figure 13. As a result of the communication between these levels, they could be constantly adjusted to an increased understanding and renewed, through enhanced impact identification and management to relevant strategic considerations and through renewed strategic considerations also to improved or re-adjusted impact identification and so on.

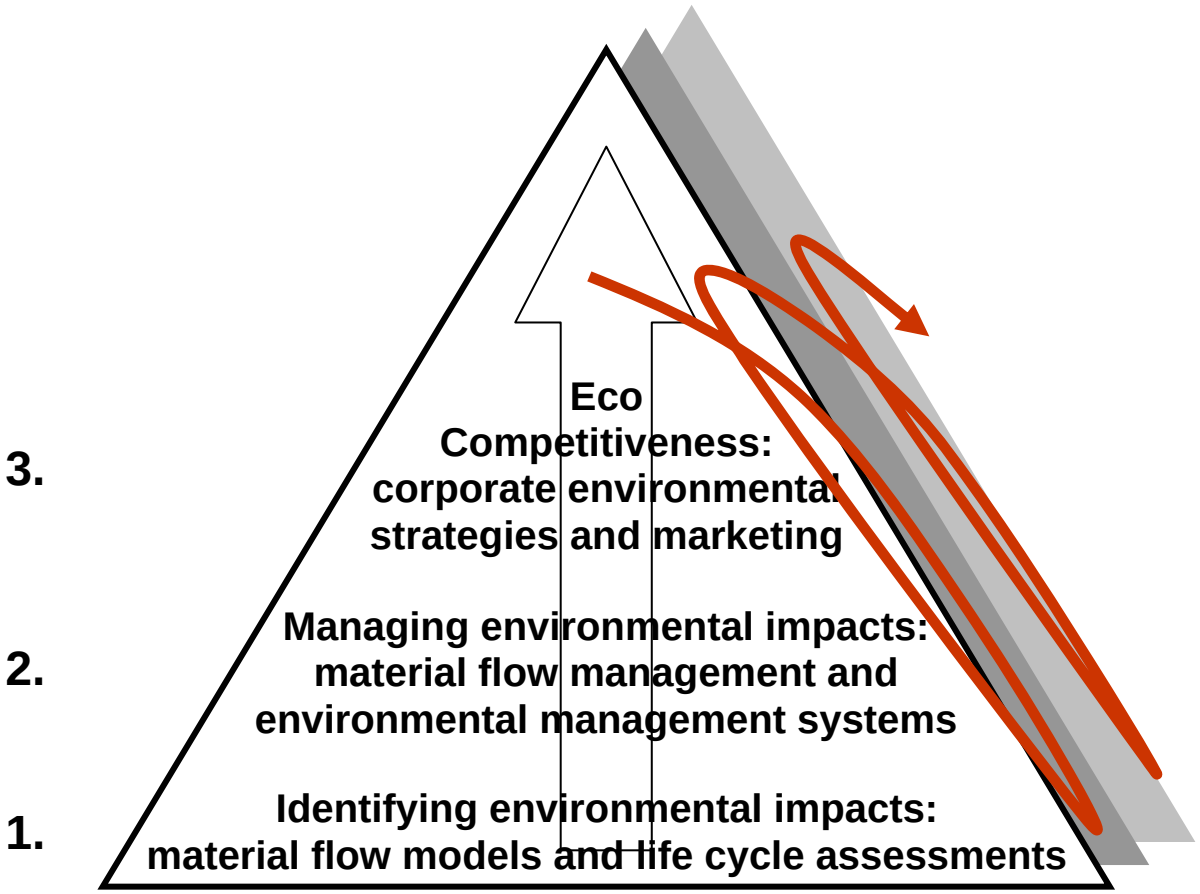

FIGURE 13 Continual development through knowledge creation in the case project (modified from Pesonen 2003)

The findings therefore imply that learning and knowledge creation processes as well as co-operation and interaction are essential for the advancement of environmental management efforts in companies. Consequently, LCM and corporate environmental management can be seen as highly dynamic and interactive processes, where companies re-organise operations and strategies. Companies then adjust their environmental management dynamically to internalized knowledge, but also affect their operational environment by externalizing the knowledge that they hold.

7.3 Quality of research

7.3.1 Methods and qualitative data

For the used literature sources, it is estimated, that many of the key writings often referred to in the field of LCM and corporate environmental management in relation to environmental improvements and their key concepts were found. However, due to the time period required by the realization of the research, some of the latest writings may have been overlooked.

In interpreting the interview data, the observations were vital. In the interview data, there were many nuances that affect the interpretations significantly. There were many indirect references to incidents of conflict or tensions caused by market situations or references to other such contextual factors. Without the observation data it would have been difficult or impossible to grasp these nuances. It seems that tacit knowledge needed to be employed in order to interpret situations of interaction and co-operation. An explicit reporting of this tacit knowledge in the research report in all cases was, however, found impossible.

The selection of the interviewed actors did not include all the operators of the case project. However, there was room for elaborating thoughts in the interview situations, which confirmed the suitability for a semi-structured questionnaire. The interview data gave an interesting representation of the actors' perceptions of the process, where the management level perspectives were emphasized. This choice reflected the usability of the LCM concept from the perspective of strategic and other management-level considerations.

The interviews did not explicitly use the term or related concepts describing environmental innovations, since it was assessed, that this way the interviewed actors more freely express all beneficial developments or improvements. Consequently, the notions of the experienced importance of interaction and co-operation were evident in the interview data, and the improvements or outcomes were not only restricted to technical improvements.

In qualitative research, the validity often greatly depends on the research process (Eskola & Suoranta 1998). In this research process the final focus of the research could have been determined earlier, in order to avoid the collection of unnecessary observation data and improve the focus on the chosen issues.

I was taking part in the case project actively and therefore also a subjective role in it and an understanding of it was formed. As stated by Easton (1995), there is always a possibility of a bias in research. One has to accept being a part of the research process. The research process is also a social activity in itself, with possible implications (Easton 1995). A participation in the case project was considered inevitable for the understanding of the process and validity of the interpretations, because each situation is unique and its meaning is a function of the circumstances and the individuals involved (see Remenyi et al. 1998).

The reliability of qualitative data has been stated to rise from its authenticity, meaning that the informants' expressions concern same phenomena as studied by the researcher. The relevance of the interviews and observations concerning the studied phenomena also contributes to the reliability (Ahonen 1996). To ensure that the findings analysed would correspond to the intentions of the observed and interviewed actors, the interpretation and analysis of the qualitative data focus on findings which are directly stated or implied and also reoccurring in the data.

Although the interview and observation data in some cases provides enlightening phrases and wording, a more detailed textual analysis would not serve the purposes of this research. On the contrary, employing such methods

would have required a deeper analysis of many contextual factors, such as market situations, competition and corporate culture. A more detailed analysis of the qualitative data would have required a much narrower focus and therefore would have been conflicting with the exploratory research strategy that enabled a larger and a more holistic focus. Since there was not much to be found in earlier research on what would be the most essential questions in the interaction and co-operation for LCM, a wider focus was in any case necessary.

However, the role of the researcher in drawing the interpretations on the contents and features in the learning processes was significant. During the research process carrying out the research process in practice enlightened some of the assumptions that I held on what the possible findings would be. It was discovered that I had actually assumed to find traces of more straightforward innovation processes. However, when it was discovered that learning was significant in enhancing innovativeness in general and that the outcomes of the processes were often not the expected ones, although experienced beneficial, I needed to re-evaluate my assumptions. Also, the central importance of interaction and co-operation for learning processes caused re-evaluation of the assumptions on the nature of learning. Based on previous knowledge I assumed the learning processes to be much more individual and straightforward, proceeding clearly from observations to changes in behaviour.

The observation of the case project and a thorough analysis of the interview data therefore revealed that I had also to some extent adopted the technically oriented realist assumptions that innovation and corporate environmental management descriptions often hold. During the process it was also discovered, that due to my specific experiential and theoretical background, my interpretative framework and assumptions were sometimes different from the ones that the other actors held. Therefore, in some cases also the made interpretations on the situations differed. It was observed that in many cases also the actors held technically oriented assumptions of the innovation process and did not see the constructed knowledge as a beneficial outcome, for example, although it could also be observed that it was used for environmentally or economically beneficial purposes.

In general, the research design combining two different types of approaches and knowledge with varying philosophical background assumptions was considered challenging.

7.3.2 The findings

Corporate environmental management is a relatively new field of study. Therefore, many new concepts have been introduced and their actual content defined along practical realizations. The elaboration of the definitions of LCM here may somewhat clarify the content. The conclusions drawn on the wide definitions and somewhat ambiguous content of concepts also indicate needs for further development.

A weakness of conceptual work conducted by an individual researcher is that it may not be diffused among practitioners. However, in-depth analysis and formation of concepts is difficult in groups due to the conflicting views and backgrounds of experts, as stated by the working group report on LCM (Jensen & Remmen 2004).

The findings from only one case project can not introduce features for LCM that could be generalized as such. There were many case-specific features, such as the specific, situational context that affects the realization and interpretations of LCM. Also, subjective perspectives of the interviewed actors and the researcher affect the interpretations. However, a qualitative and data-driven analysis of the experiences is provided. With the progressive focusing, the exploration of the phenomenon of LCM could cover many inter-related issues. Also, the data- driven interpretation is expected to bring authentically new information on the ways learning processes may affect environmental work in companies. However, an identified weakness in the exploration is that the focusing on the indicated significance of interaction and co-operation produces information mainly on the factors supporting development, with only some indications of the hindering factors. Therefore, the results have an optimistic tone. Also more understanding is needed on the barriers for environmental work, especially in intra-organizational co-operation.

The chosen perspective is estimated beneficial for further development, since there are not many studies that would describe also the experiences on interaction and co-operation of LCA or LCM processes. Also, the attempted bridging of technological, social and environmental perspectives on change will hopefully be elaborated further.

7.4 Needs for further research

In general, based on both conceptual and data-driven findings, this research demonstrates that interaction and co-operation are important in generating environmental improvements in product life cycles, and therefore need to be studied further.

Since interaction and co-operation are strongly related to knowledge creation and innovativeness related to environmental considerations, it is an interesting question how these processes actually occur, as an interaction between the individual beliefs, values or motives and company-level cultures, interests and motives regarding environmental considerations.

An increased level of environmental information does not automatically lead to an increased environmental friendliness in decision-making processes. There were some interesting indications in the observations and interviews that in trade-off situations the economic factors do not always overrule the environmental considerations in corporate decision-making. Some decision-making processes, for instance, seemed to be affected by individual values. Also

indications on value negotiations between what could be considered as individual and corporate values were observed. Therefore the relationships between economic and environmental premises and the factors affecting decision-making processes provide interesting topics of research in more detail.

It has been previously noted, the ISO-standardized LCA framework does not offer any guidelines on how to treat or negotiate the economic and various environmental value-based questions when LCA information is interpreted for decision-making purposes. (see e.g. ISO 14040, Loikkanen et al. 1999) As in the discussions concerning the decreasing of the cooling of beverages a common understanding of the environmental burdens as well as the economic benefits of decreasing the cooling was formed among the participants. (See sub-chapters 5.2, 6.1.2) Due to the understanding, these improvements were then realized by competing retail operators. Therefore, a question for further studies is raised, if decision-making in situations with complex value questions and competitive situations can be aided by means using interaction and co-operation of actors and companies to orientate value judgements and to relieve the confusion and frustration of actors.

YHTEENVETO (Finnish Summary)

Yritysten on yhä tarpeellisempaa arvioida tuotteidensa elinkaarten ympäristövaikutuksia niihin liittyvien lainsäädännöllisten vaatimusten jatkuvasti lisääntyessä. Elinkaariajattelu voi myös tarjota mahdollisuuksia kehittää liiketoimintaa. Tuotteiden elinkaarijohtaminen, LCM eli life cycle management, on uusi käsite joka kuvaa pyrkimyksiä tutkia ja kehittää tuotteiden elinkaaren ympäristötehokkuutta. Se on määritelty monin eri tavoin. Käsitykset elinkaarijohtamisen tavoitteista ja toiminnoista vaikuttavat siihen, millaisia parannuksia elinkaarijohtaminen voi tuottaa. Tässä tutkimuksessa tarkastellaan sitä, mitä elinkaarijohtamisella tarkoitetaan ja millaista käytännön toimintaa siihen liittyy. Yritysten ympäristöjohtamisen tutkimukset pohjautuvat usein realistisiin taustaoletuksiin ja keskittyvät teknologisiin muutoksiin keinoina tuottaa ympäristöparannuksia. Siten sosiaaliseen vuorovaikutukseen, subjektiivisiin kokemuksiin ja ymmärrykseen liittyvät tekijät usein ohitetaan, vaikka ne voivat olla keskeisiä ympäristötyön edistämiseksi yrityksissä. Tutkimuksen fenomenologinen lähestymistapa ja eksploratiivinen strategia mahdollistavat näiden tekijöiden huomioimisen ja erilaisten tutkimusmenetelmien yhdistämisen. Tutkimuksen ensimmäisessä osassa tarkastellaan tulkitsevan käsitetutkimuksen avulla elinkaarijohtamisen määritelmiä. Niiden mukaan elinkaarijohtamisen ydintoimintoja ovat (1) ympäristötiedon tuottaminen ja hyödyntäminen, (2) ympäristöparannusten toteuttaminen ja (3) vuorovaikutus ja yhteistyö. Kun määritelmissä yksilöityjä ympäristöparannuksia verrataan muihin käsitteisiin, todetaan että ne voidaan nähdä innovaatioina. Siten elinkaarijohtaminen liittyy innovaatioihin. Tutkimuksen toisessa osassa tarkastellaan kokemuksia projektista jossa tutkittiin ja kehitettiin suomalaisten juomapakkausten elinkaaren ympäristötehokkuutta vuosina 2000-2002. Tapaustutkimuksen aineistona käytetään haastatteluja, osallistuvaa havainnointia ja projektin dokumentointia. Osallistujat kokivat projektin hyödylliseksi erityisesti sen tuottamien oppimiskokemusten vuoksi. Aineistolähtöinen tarkastelu osoittaa, että toimijoiden ja yritysten välinen yhteistyö ja vuorovaikutus mahdollistivat ja tukivat kollektiivista, jatkuvaa ja kokemuksellista oppimista ja uuden tiedon luomista. Vuorovaikutus ja yhteistyö olivat merkittäviä koska ne kehittivät osallistujien asiantuntijuutta, auttoivat motivoimaan ympäristötyöhön ja ylittämään siihen liittyviä esteitä. Vuorovaikutus ja yhteistyö myös tukivat innovatiivisuutta ja ympäristöparannusten toteuttamista tuotantoverkostoissa. Tutkimuksen perusteella voidaan päätellä että elinkaarijohtamiseen liittyvä toiminta voi tuottaa uutta tietoa ympäristönäkökohdista ja ymmärrystä niiden yhteyksistä yritysten talouteen, kuten myös käytännön parannuksia toiminnoissa ja tuotteissa. Siten elinkaarijohtaminen voi myös vauhdittaa dynaamisen ja vuorovaikutteisen ympäristöjohtamisen kehittymistä yrityksissä ja siihen liittyvää strategista ajattelua.

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APPENDIX 1 – The interview questions

Functional development of the eco-efficiency management of the foodstuff - a SWOT survey

The target of the survey is to collect and analyse views of the industry and trade representatives on the strengths, weaknesses, opportunities and threats (SWOT) of the networked and product-based environmental management of products. Special interest is on how the results and experiences gained in two recent Finnish research projects ('Food Chain'- and 'Beverage Packaging' - project) have been utilised or could be utilised in the management and marketing practices of the participant companies. The results of the survey will be used to clarify the interests and the utility expectations of the companies regarding the application and the future development and of the procedures and tools for the networked environmental management of products.

The material for the survey will be collected by means of structured interviews of company representatives.

The interviews are conducted by student Julien Desrues or researcher Sanna Poikkimäki from Environmental management, School of Business and Economics, University of Jyväskylä.

The results will be analyzed and interpreted by both researchers from Maatalouden tutkimuskeskus, MTT and University of Jyväskylä. They will be applied for evaluation of the functionality and applications of the projects as well as for further method development for networked and product-based environmental management and particular needs of participating companies. The results will also be applied in the development of the national food quality strategy of the Ministry of Forestry and Agriculture.

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Questionnaire
Haastattelukysymykset

LCA and business perspectives
Elinkaariarviointi ja liiketoiminta

1
Why did your company participate in the Foodchain / beverage packaging LCA project? Was your primary goal to develop your own processes, network innovations, or rather to produce information for your external communication?

Miksi yrityksenne osallistui Foodchain- projektiin / Juomapakkausprojektiin? Oliko tärkein tavoite kehittää omia prosesseja, verkostoinnovaatioita vai esim. tuottaa tietoa sidosryhmäviestintää varten?

2
Did the project increase your understanding of product-based environmental assessment or the LCA method? Why? How should the methods be developed?

Lisäsikö projekti elinkaariarvioinnin tai tuotepohjaisen ympäristöhallinnan tuntemustanne? Millä tavoin? Miten menetelmiä tulisi mielestänne kehittää?

3
Do you think that this kind of project supports other development work in your company? How or what kind of processes?

Tukeeko tämän kaltainen projekti mielestänne muuta kehitystyötä yrityksessänne? Miten ja millaista kehitystyötä?

4
Did the project affect the strategic thinking in your company or your opinion of the key success factors now or in the future?

Vaikuttiko projekti (sen prosessi tai tulokset) yrityksenne strategiseen suunnitteluun tai käsitykseenne yrityksenne menestystekijöistä nyt tai tulevaisuudessa?

5
Do you think that this process is bringing benefits to your company in general? What kind of benefits?

Toiko projekti käsityksenne mukaan hyötyjä yrityksellenne? Millaisia?

Participation & motivation
Osallistuminen ja motivaatio

6
What was your attitude towards this project beforehand and after it?

Mikä oli asenteenne projektia kohtaan sen alussa ja sen jälkeen?

7
Was your everyday work or attitude towards environmental matters changed by the project? How?

Vaikuttiko projekti jokapäiväiseen työhönne? Millä tavoin?

8
Do you think that the everyday work or attitude towards environmental considerations of people in your company was affected somehow? How?

Vaikuttiko projekti yrityksessänne tehtävään jokapäiväiseen työhön yleensä tai työntekijöiden asenteisiin ympäristöasioihin liittyen? Millä tavoin?

Environmental & economic efficiency improvements
Ympäristötehokkuuden ja taloudellisen tehokkuuden parannukset

9
What kind of improvements have you made as a result of the study or based on environmental efficiencies in general? Have you changed your raw-materials, processes, packaging, use of energy or any other changes?

Millaisia parannuksia yrityksessänne on tehty joko projektiin liittyen tai ympäristötehokkuden parantamiseksi yleensä? Toiko se muutoksia raaka-aineisiin, prosesseihin, pakkaamiseen, energian käyttöön tai muita vastaavia muutoksia?

10
Are you planning to make any environmental efficiency improvements in your company in the future? What kind of changes?

Suunnitteletteko parantavanne yrityksenne ympäristötehokkuutta tulevaisuudessa? Millä tavoin?

11
Have you changed your products? Will you make product changes to improve their environmental efficiencies? What kind of changes?

Oletteko muuttaneet tuotteitanne? Suunnitteletteko tuotteiden muutoksia niiden ympäristötehokkuuden parantamiseksi? Millaisia muutoksia?

12
Do you think it is possible to make product changes that will improve their environmental efficiency and also affect customer behaviour in the future?

Luuletteko että tulevaisuudessa on mahdollista toteuttaa tuotteiden muutoksia jotka parantaisivat niiden ympäristötehokkuutta ja myös vaatisivat muutoksia kuluttajakäyttäytymisessä?

13
Have the realized changes been cost efficient or have you made any investments for improvements?

Ovatko toteuttamanne muutokset olleet kustannustehokkaita tai oletteko investoineet kehityskohteisiin?

14
Will the planned changes be cost efficient or will you make any investments for improvements?

Tulevatko suunnitellut muutokset olemaan kustannustehokkaita vai investoitteko ympäristöparannuksiin?

15
What have been or will be the most significant barriers for realizing improvements, for example finding the resources, overcoming resistance among the personnel or general understanding on what is an environmental improvement?

Mitkä ovat olleet suurimpia esteitä parannuksille, esim. resurssien allokointi niitä varten, vastustus henkilöstön keskuudessa vai yleensä ymmärrys siitä mikä on ympäristöparannus?

16
Do you think the research process added value to the product? Do you you think that it could do so? What kind of added value? How? Do you think that this added value could affect the demand?

Luuletteko että tutkimusprosessin avulla tuotettiin lisäarvoa tuotteillenne? Luuletteko että vastaavalla prosessilla voitaisiin tuottaa tuotteille lisäarvoa? Millaista lisäarvoa? Millaisen prosessin tulisi silloin olla? Luuletteko että lisäarvo voisi vaikuttaa kysyntään?

Stakeholder communication & co-operation
Sidosryhmäviestintä ja yhteistyö

17
Have you built new ways of co-operation with your stakeholders with this research process? What?

Oletteko luoneet uusia yhteistyömuotoja sidosryhmienne kanssa tutkimusprosessin aikana? Millaisia muotoja?

18
How do you see the linkage of the product-based environmental management and communication to the consumer? What could be the possible utility of it? How the utility could be gained?

Millaisena näette tuotelähtöisen ympäristöjohtamisen ja asiakasviestinnän välisen kytkennän? Millaista hyötyä siitä voisi olla? Miten hyötyjä voitaisiin paremmin saavuttaa?

19
What other forms or forums for stakeholder dialogue or co-operation do you have at the moment, for example how do you communicate with your suppliers? How do you get feedback from your customers on your products? Do you co-operate with non-governmental organisations?

Millaisia muita sidosryhmädialogin tai yhteistyön muotoja teillä on? Esim. millä tavoin viestitte alihankkijoidenne kanssa? Tai millä tavoin saatte palautetta asiakkailtanne? Teettekö yhteistyötä myös muiden kuin yritysten, esim. järjestöjen tai yhteisöjen kanssa?

20
Will you need new forms of co-operation with your stakeholders in the future? For what purposes or what kind of co-operation?

Tarvitsetteko uusia sidosryhmäyhteistyön muotoja tulevaisuudessa? Mitä tarkoitusta varten tai millaisia yhteistyön muotoja?

Conclusions
Yhteenveto

21
What do you think about product-based environmental management in general?
- strengths?
- weaknesses?
- opportunities?
- threats?

Mikä on käsityksenne tuotelähtöisestä ympäristöjohtamisesta yleensä?
- vahvuudet? - heikkoudet?
- mahdollisuudet?
- uhat?