Faculty of Technology and Science
Environmental and Energy Systems

Helén Williams

Food Packaging for Sustainable Development

DISSERTATION
Karlstad University Studies
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Abstract

Packaging has been on the environmental agenda for decades. It has been discussed and debated within the society mainly as an environmental problem. Production, distribution and consumption of food and drinks contribute significant to the environmental impact. However, consumers in the EU waste about 20% of the food they buy. The function of packaging in reducing the amount of food losses is an important however, often neglected environmental issue.

This thesis focuses on the attributes of packaging that can be used to preserve resources efficiently and reduce the environmental impact of the food-packaging system. The service perspective is used to increase knowledge about consumer interaction with packages. Fifteen packaging attributes, for example, 'easy to empty', 'hygienic' and 'contain the right quantity', were identified as influencing the amount of food losses at the consumer. The result showed that there are potentials to both increase consumer satisfaction and decrease the environmental impact of the food-packaging system, when new packaging design reduces food losses. A model was developed that calculates the balance of environmental impact between reduction of food losses, and more packaging material. The result showed that it can be environmentally motivated to increase the environmental impact of packaging, if the amount of food losses is reduced. This is especially true for food items with high environmental impact, e.g. meat and dairy products, and for food items that have a high share of loss, e.g. bread.

I have also explored to what extent packaging can influence food losses in households. The study showed that about 20% to 25% of household food waste was related to packaging. The households noted three packaging attributes as the main causes for food losses; 'too big packaging', 'difficult to empty' and 'best-before-date'.

Finally there is a discussion of packaging research in the context of sustainability principles, and suggestions for further research.

Key words: Packaging, sustainable development, service perspective, food losses, food waste, consumer interaction, life cycle assessment - LCA, consumer value

Sammanfattning

Under de senaste årtiondena har förpackningen ofta framställts som ett stort miljöproblem i samhällsdebatten. Att miljöpåverkan från livsmedelsproduktion är betydligt större har inte diskuterats i lika stor utsträckning. Förpackningen står ofta för 5-10% av miljöpåverkan av ett förpackat livsmedel. Det har visat sig att konsumenter i EU slänger ca 20% av den mat som de köper hem och eftersom livsmedel är mycket resurskrävande, ger detta upphov till en både stor och onödig miljöpåverkan. Matsvinn är också ett etiskt problem eftersom en stor del av jordens befolkning inte har tillräckligt med mat utan svälter.

Den här avhandlingen har undersökt olika förpackningsegenskaper som kan bidra till effektivare resursutnyttjande och minskad miljöpåverkan från förpackad mat, dvs. förpackningen ihop med livsmedlet. För att öka förståelsen för hur olika förpackningsegenskaper påverkar konsumenternas beteende har tjänsteperspektivet spelat en stor roll. Med ett tjänsteperspektiv så studeras själva produkten och de tjänster som utnyttjas när produkten används. Resultaten har bland annat visat att det är många förpackningsegenskaper som kan påverka mängden matsvinn. Exempel på sådana egenskaper är att förpackningen är lätt att tömma, att den är hygienisk och innehåller lagom mängd mat för hushållets behov. Konsumenten uppskattar ofta de egenskaper som kan minska mängden matsvinn, vilket gör att det går att kombinera en minskad miljöpåverkan med en ökad kundtillfredsställelse. Det är viktigt att nya förpackningslösningar minskar mängden matsvinn. Ur miljösynpunkt är det bästa alternativet att samtidigt minska matsvinn och förpackningens egen miljöpåverkan. Går inte detta att kombinera är det nästa bästa alternativet oftast att utveckla förpackningar som minskar matsvinnet även om förpackningarna i sig får en ökad miljöpåverkan. För att kunna räkna ut hur mycket miljöpåverkan från förpackningen maximalt kan tillåtas att öka om den minskar mängden matsvinn har en matematisk modell utvecklats. Resultaten från beräkningarna har visat att det är en bra miljöstrategi att använda förpackningar för att minska matsvinn. Detta är särkilt viktigt för livsmedel med en hög miljöpåverkan, som kött och mejerivaror, och för livsmedel som det slängs mycket av som t.ex. bröd.

I en av studierna mätte olika hushåll hur mycket livsmedel som slängs och noterade i en dagbok hur mycket av det slängda som kunde relateras till förpackningen. Det visade sig att ca 20-25% av den mat som slängdes av

hushållen beror på förpackningsegenskaper, främst 'för stor förpackning', 'svår att tömma helt' och 'bäst före datum'.

I avhandlingen diskuteras även hur begreppet hållbar förpackningsutveckling kan inkludera de mål och principer för en hållbar utveckling som finns i litteraturen. Forskningen om hållbar förpackningsutveckling, från den enskilda förpackningen till de globala perspektiven, har strukturerats i fem nivåer. Även ett antal viktiga frågor om processen i en hållbar förpackningsutveckling har analyseras, t.ex. ständiga förbättringar och vikten av integrerande perspektiv och deltagande.

Förpackningsdirektivet 94/62/EG, som fokuserar på förpackningsmaterial samt återvinning av förpackningar, kritiseras för att negligera den betydligt viktigare miljöaspekten av att minska förluster av framför allt mat. Denna ensidiga och långvariga fokusering på förpackningen som produkt riskerar att öka den totala miljöpåverkan.

I avhandlingen presenteras en mer balanserad syn på förpackningen än den som ofta hörs i samhällsdebatten. Förpackningen i sig är inte "ond eller "god" för miljön. Den kan framförallt bidra till en minskad miljöpåverkan om dess egenskaper för att minska matsvinnet utvecklas och kanske därmed öka möjligheterna för fler människor att kunna äta sig mätta.

Acknowledgements

In this process to become a researcher many people have, in different ways contributed, and I am very thankful to you all.

Bengt Månsson was my first supervisor and he was the one who took me on this journey and I have always felt his support. He let me choose areas and questions very freely, in order for me to feel committed to the process. He has given constructive comments regarding early versions of the papers. Bengt has a great talent to provide a broad range of insightful perspectives in any discussion. Thank you for this, Bengt.

I knew from the start that I needed someone with whom to work closely, because I am not a "lone wolf". I was able to talk Fredrik Wikström into joining me in this new research field in our department. He was doubtful in the beginning however, I provided him with a lot of enthusiasm about what great research we could do together and what fun I would be to work with. I am not so sure about that last part anymore, because there have been times during this process when I have not been all that 'fun'. However, there are not words enough for how important Fredrik has been as my supervisor and co-writer. He is supportive, a constructive reader of manuscripts, committed and a good friend. We have had long and intense discussions about research question and research design, where we usually complement each other well. I will be forever grateful to you, Fredrik for supporting me through this journey. I hope that together we will continue to try to "save the world", developing this interesting and important research.

I want to thank Martin Löfgren, for having the courage to write together with me in my first paper. You have been very open to our perspectives and I feel that we continuously are trying to learn from each other. Anders Gustafsson has also joined the co-writing. Thank you, Anders for your open attitude and constructive comments about methods and the drafts. Tobias was a co-writer in paper four; thank you for helping with collecting empirical material and doing statistical calculations. I do hope there will be more opportunities for us all to write together and learn more from each other in the future. I want to express my gratitude to the entire group at CTF and the open and welcoming atmosphere you have created. I have always felt like one of the group when I have participated in different kinds of meetings. Thank you also for inviting us

into the program financed by the European Regional Development fund and Region Värmland. I do hope that our cooperation will continue to develop over the years to come.

I want to express my excitement about the cooperation with Annika Olsson and Daniel Hellström, co-writers in Paper V, and their colleagues in Packaging Logistics at Lund University. With your knowledge about the role of packaging earlier in the distribution chain, and from a service perspective, I feel that we complement each other very well. Thank you for your open attitude and interest in our views in this matter. I strongly believe that we will continue to do great interdisciplinary research together.

I also want to express my appreciation and admiration of my colleague Karl-Erik Eriksson. You are an inspiration because of your commitment to the work towards a sustainable development and you are always curious and interested in new perspectives. Thank you for discussing research perspectives with me, reading and contributing with constructive criticism of the papers two and three and the thesis. Thank you, for taking me with you to Ghana.

Every time I have asked for his help, Ola Holby has taken the time to read and deliver constructive comments regarding early versions of the papers and the formulations in my thesis, thank you for this.

Furthermore I want to thank my language editors Karolina Schultz Danielsson and Mike McArthur, for being fast and reliable.

I am very lucky to work at the best department there is. This is an environment where there is laughter, political debates, pedagogic discussions, small chats and supportive comments. In the past months I feel like I have only taken energy from the colleagues in the coffee-room. I hope I will be able to return it when I come out on the other side. It is difficult to thank any one person more than another so let me just say, you are all very good people and I enjoy working with you.

I have appreciated the co-operation and shared projects with the colleagues at "The Packaging Arena". I hope that we will continue to find interesting projects on which to co-operate. Thanks for good co-operation to: Anders Eliasson, Henrik Ahlgren and Louise Ungerth.

Special thoughts go my friends who have supported me over the years. Agneta and Lars, thank you for all your care and supporting comments. Thank you, Pia, Helena, Viveca, and all the others in our "midsummer-group"; it means a lot for me that we can be there for each other when needed. I want to express my gratitude to all the families around me, and my own family, who have provided me with many dinners, fun and relaxing moments, caring thoughts and supportive comments, Maria and Lars, Katarina and Tomas, Anna and Sven, Elisabet and Jonas, Karin and Hans, Anneli and Jörgen and more…

Thank you to mum and dad for your care and for always believing in me and for helping out with the children when needed. Thank you, Petra and Tony and Andreas and Lina for being there, sharing family holidays and also for helping to take care of the children when it has been too hectic. I love you all.

Last but not least I want to say thank you, Mats, Hanna, Jacob and Lucas. My family is the best there is. I am very fortune to get your love and share many fantastic moments with you. Mats, you are my biggest supporter; all those times when I lacked confidence you overwhelmed me with comments about how fantastic I am to help me to get back on track. Thank you for being there and for always supporting me and loving me as I am. Hanna, Jacob and Lucas have all shown patience these last months, when I have worked more hours than in very many years. There have been many questions about when my book would be ready. You have given me massage, made me coffee and given me lots of supporting comments and love. The book will soon be ready and I hope that this research and the research to come can contribute towards a better future for you and other children. However, since you came into my life you are my number ones and now, I only hope for a long, sunny and relaxing summer with you!

Hammarö, May 2011

Helén Williams

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Paper II: Wikström F, Williams H. 2010. Potential environmental gains from reducing food losses through development of new packaging - a life-cycle model. Packaging Technology and Science; 23: 403–411.

Paper III: Williams H, Wikström F. 2011. Environmental impact of packaging and food losses in a life cycle perspective: a comparative analysis of five food items. Journal of Cleaner Production; 19: 43-48

Paper IV: Williams H, Wikström F, Otterbring T, Löfgren M, Gustafsson A. 2011. The influence of packaging on household food waste. *Submitted to Journal of Cleaner Production*

Paper V: Wikström F, Gustafsson A, Hellström D, Löfgren M, Olsson A, Williams, H. 2011 Sustainable packaging development - one step further. *To be submitted for publication in Journal of Cleaner Production*

1 Introduction

> *"Starvation is the characteristic of some people not having enough food to eat. It is not the characteristic of there being not enough food to eat." Amartya Sen,*

The evidence from the natural sciences that humans are severely damaging the planet is today obvious. This can be expressed as that the natural resources are being used over nature's carrying capacity (e.g. Lovins et al., 1999; Rockström et al., 2009) and the speed at which these changes occur today offers warnings signals (Young et al., 2006). The resources are unequally distributed over the world and a large part of the population is starving (FAO, 2010). Today the main problem is the difficulty of sharing and distributing food to all people; in the future there is a risk that there will not be enough food for everybody. To solve these problems is complicated because the world population is still growing. I strongly believe that I have a responsibility to do what I can to change some of the negative trends of today. This is a responsibility not only to my own three children but also to the generations to come.

My area of interest is food and packaging. Food is needed by all humans daily and therefore causes large environmental impacts. Production, distribution and consumption of food and drinks contribute significantly to the environmental impact. Food and drinks represent about 20 - 30% of the environmental impacts of the consumption in the EU. Products from animal origin cause the greatest environmental impact (Tukker and Jansen, 2006; Cederberg et al, 2009). As people in developing countries get richer, the food intake changes and the people begin to consume food with higher environmental impact (more meat) and that increases resource use and the environmental impact from food consumption in these countries.

Packaging[1] has been on the environmental agenda for decades. It has been discussed and debated within the society as an environmental problem and the focus has been on the packaging material (Robertson, 2006), including recycling options (Eriksson et al, 2007). However, as Svanes et al (2010) state, packaging affects the total environmental impact of the system in several other ways. For example, the packaging design influences the distribution efficiency and usage

[1] "Packaging shall mean all products made of any material of any nature to be used for the containment, protection, handling, delivery and presentation of goods, from raw materials to processed goods, from the producer to the user or the consumer" *(European Council, 1994)*

attributes, such as how easy it is to empty the package. Therefore, instead of considering packaging only as an environmental problem, this thesis focus on the attributes of packaging that can be used to preserve the resources more efficiently and reduce the environmental impact.

Packaging is a starting point due to my experiences from working with environmental issues at a paperboard producer in Sweden. In the middle of 1990 packaging was something bad in society and something expressed as unnecessary. The quote from the Swedish Environmental and natural resource department (1992) can serve as a common view on packaging back then.

> "Everything we construct, build and produce is finally turned into waste….Many things, such as buildings, art and expensive cars are maintained in order for them to last as long a time as possible. Newspapers and food residues we often waste after only one day. Other things have perhaps only some hours' lifespan, such as **packaging** and different kinds of throwaways". *My translation.*

This view is still expressed by many people today, although there have been some changes in society in the past few years with the growing attention to the food waste issue.

There are both bad and good environmental aspects of packaging. I have experienced the benefits of the Directive 94/62/EC on Packaging and Packaging Waste, with new packaging solutions, new materials and less material per packaged unit; all examples that have reduced the environmental impact of packaging. However, as this continues to be the main environmental focus from policy makers and consumers, there is a risk that the material reductions turn into an environmental problem, with increasing food losses, if packaging loses its protection ability. The risk for environmental sub-optimization in the food-packaging system can be reduced with an increased focus on what well designed packaging does; e.g. protection during transport and providing information and convenience for consumers.

1.1 Aim

The overall aim of this thesis is to contribute to knowledge on how food packaging can contribute to a more sustainable development.

Specifically, my aims are to:
- increase the knowledge of how packaging attributes influence consumer behavior with regard to the environmental outcome, especially the influence on food waste.
- develop a model that can be used to minimize the environmental impact of the food packaging system.
- increase knowledge about what proportion of household food waste is related to packaging.
- develop the concept of "packaging for sustainable development" to include the main aims and principles of the sustainable development literature.

The research hopefully can be useful for businesses, authorities and consumers in realizing the potential for packaging to contribute to sustainable development.

1.2 Appended papers and contributions by the author

Paper I: A life cycle perspective on environmental effects of customer focused packaging development.

This paper was co-authored with Dr. Fredrik Wikström and Dr. Martin Löfgren. The idea for this paper came from me and I designed the research process. I was the main author of this paper and conducted the literature search for identifying environmental issues in the food-packaging system. Dr. Löfgren wrote the chapter on the description of customer data. The completion of the paper was a joint effort by Dr Wikström and me.

The paper was published in Journal of Cleaner Production 2008.

Paper II: Potential environmental gains from reducing food losses through development of new packaging - a life-cycle model.

This paper was co-authored with Dr. Fredrik Wikström, who is the main author of the paper. We contributed equally to the idea and in the designing of the study. I contributed with the empirical data. Dr. Wikström is the engineer of the mathematical model and made most of the mathematical calculations in the paper. The completion of the paper was a joint effort by Dr Wikström and me.

The paper was published in Packaging Technology and Science 2010.

Paper III: Environmental impact of packaging and food losses in a life cycle perspective: a comparative analysis of five food items.

This paper was co-authored with Dr. Fredrik Wikström. We contributed equally to the idea and in the design of the study. I was the main author of this paper and conducted the empirical work. The completion of the paper was a joint effort by Dr Wikström and me.

The paper was published in Journal of Cleaner Production 2011

Paper IV: The influence of packaging on household food waste.

This paper was co-authored with Dr. Fredrik Wikström, Tobias Otterbring, Dr. Martin Löfgren and Prof. Anders Gustafsson. We contributed equally to the idea and in the designing of the study. I was the main author of this paper and did most of the descriptive analysis of the data. Martin Löfgren and I designed the diary and questionnaire. Tobias Otterbring and I conducted the empirical data collection. The statistical significance analysis was done by Tobias Otterbring. The completion of the paper was a joint effort by all the authors.

This paper is submitted to Journal of Cleaner Production

Paper V: Sustainable packaging development- one step further.

This paper was co-authored with Dr. Fredrik Wikström, Dr. Martin Löfgren and Prof. Anders Gustafsson, Dr. Annika Olsson and Dr. Daniel Hellström. Dr. Wikström and I contributed equally to the idea and in the designing of the study and with the literature studies. Dr Wikström was the main author of this paper. The completion of the paper was a joint effort by all the authors.

This paper is a working paper, to be submitted.

1.3 Outline of the thesis

This thesis is made up of 11 chapters.

Chapter 1 contains an introduction to the research area.

Chapter 2 is an introduction to sustainable development. Some theoretical approaches, sustainable development as a process and some principles for how to work with sustainable development are presented.

Chapter 3 is an introduction to the service perspective. This includes the framework of Product-Service-System and its relation to sustainability and the theoretical departure of how the service perspective is approached in this thesis.

Many packaging attributes (Paper I) can influence the amount of food losses and they are presented in *Chapter 4*.

Chapter 5 presents results from calculations of the balance between environmental impacts from packaging versus food losses, mainly results from Paper II and III.

Chapter 6 is about the behaviour and attitudes regarding household food waste, mainly results from Paper IV.

In *Chapter 7* I propose a progression of the packaging research to encapsulate the principles of sustainable development (Paper V).

In *Chapter 8* the contributions from this thesis are put forward.

In *Chapter 9* perspectives on the research process and some methodological implications are discussed and some important future research questions and areas are discussed in *Chapter 10*.

Chapter 11 includes some personal concluding remarks.

2. Sustainable development

Sustainable development is about handling and sharing nature's resources in a "fair" way between people today and in the future. The most commonly used definition comes from the work by the Brundtland commission.

> "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (WCED, 1987)

Sustainable development is a concept that allows interpretation, as well as other political concepts like health, democracy and freedom. Humans have some knowledge about the concepts and the majority is not against those concepts.

Although the definition from the Brundtland commission is widely accepted, there is a continuous debate of how to define, interpret and operationalize[2] the concept (see for example Klauer 1999, Neumayer, 2003, Robinson 2004, Dresner 2008). There is, however a rather high consensus in the scientific literature about the core elements in the concept. These can be summarized as that humans should:

- use resources within the limits of nature´s carrying capacity.
- seek equity between generations and equity within generations.

One of the persons behind the Brundtland definition, Nitin Desai, has commented on the vagueness in an interview. He said "the issue is not defining sustainable development, but understanding it" (Dresner, 2008). This statement has been essential for us to understand what sustainable development means in the area of packaging, even if the main focus has been on the first element, that of using natural resources more efficiently.

I am in favour of the 'strong' interpretation of sustainable development where the natural resources or ecosystem services cannot be substituted by financial capital or human resources (see e.g. Hopwood et al., 2005). If humans destroy

[2] Operationalize: To put into effect, to realize *(Oxford English Dictionary)*

the basic functions in nature and interfere with the resilience[3], society will have great difficulties in satisfying even the basic human needs of food, water and shelter. If that happens there will no longer be a focus on economy as it is understood today. In other words; nature can and will survive without humans; however, humans cannot survive without what nature provides. The interpretation of sustainable development, where the resources/ecosystem-services are substituted by financial capital or human resources, is considered to be a 'weak' sustainability (Daly, 1990).

2.1 Sustainable development – a state or a process

The common use of the word 'sustainability' is as a state in the world that meets the conditions from two core elements as expressed above. The term, 'sustainable development' is used for the process towards a state that is sustainable (see for example Robèrt 2000; Hopwood et al., 2005). There are many indications that understanding the concept, continuous learning by the people involved and continuous improvements are essential. Ecosystems and social systems are changing all the time and this makes it difficult to define the state or resilience of the systems (Folke et al. 2002; Walker et al., 2004). Although it is valuable to discuss visions for a sustainable state of the world, I believe that, in the packaging context, it is more important to discuss how packaging can contribute to a more sustainable development. There is enough knowledge about the food-packaging system to take important steps in the right direction – the process towards a more sustainable development.

In the area of packaging, the industrial working group Sustainable Packaging Coalition (SPC) has made an attempt to define "The sustainable packaging". In my point of view the best way forward is not to address products as if they were sustainable. Even if humans use products of renewable material it is not sustainable it they are produced in such quantities that it threatens the access to new renewable material or if it threatens biodiversity due to monocultures. It is also not sustainable if half of the world's population cannot afford the renewable product for their basic food supply. In a globalized world where products are produced, transported and used in different contexts, with varying sources of energy and materials, with varying infrastructures and where

[3] Resilience is a "measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist" *(Holling, 1973)*.

preferences and behaviour of consumers vary and change over time, it is almost pointless to address products as sustainable. It is important to reduce uncertainty about the vocabulary in the context of sustainability and make it clear that sustainability is about the state of the world and not about individual products. However, packaging can and should contribute to a sustainable development by a more efficient and fair use of resources.

2.2 Some principles for how to reach sustainable development

In the literature, principles for how to work with sustainable development have been presented (Daly, 1990; Born and Sonzogni, 1995; IISD, 1996; Hill and Bowen, 1997; Klauer, 1999; Bellamy et al., 2001; Berke and Conroy, 2005; Karlsson, 2005; Hedelin, 2007; Dresner, 2008). Below, some of these 'how' principles (1-4) are presented:

1. Use of management approaches that are integrative[4] and focus on participation[5]. The need for participation is widely recognized in the literature of sustainable development (e.g. Klauer, 1999). These principles are widely recognized in the literature for quality management (Deming, 1994). In order for integration and participation, there must be a high agreement in the opinion about the ideals of sustainability in society (Klauer, 1999). It will be difficult to turn the development towards sustainability if majorities of people do not care about future generations or sharing resources more equally. Thereafter, it is essential to translate the ideals of sustainability into goals. Examples of goals can be to reduce the amount of fossil fuels, to avoid depletion of biodiversity, to ensure minimum standards for working labour, etc. If there is a high level of disagreement about ideals or goals, it will be difficult to gain support for concrete actions. If these ideals and goals are shared, there is a lot of information, learning and co-operation needed in order to improve the process (Kleindorfer et al., 2005). Governments also need acceptance from individuals and businesses for legislative and economic actions.

[4] Integration in the area of environmental management consists of three dimensions comprehensive/inclusive, interconnectivity and strategic/reductive *(Born and Sonzogni, 1995)*

[5] Participation-The process or fact of sharing in an action, sentiment, etc.; (now *esp.*) active involvement in a matter or event, esp. one in which the outcome directly affects those taking part. *(Oxford English Dictionary)*

2. Use of management approaches that are more holistic, future-orientated with long-term perspective and include continued improvements. The use of environmental management systems and quality management systems helps organizations to work continuously with improvements in their organizations. Long-time perspective can be handled by e.g. back-casting (Robinson, 2003; Ny et al., 2006).

3. Adoption of the precautionary principle. The precautionary principle (UNCED, 1992) often concerns judgments of the potential risk of pollution or damage by looking forward (O'Riordan and Jordan, 1995). This principle is used when discussing the use of potentially hazardous chemicals and genetically modified organisms (Karlsson, 2005). A practical example from the packaging area is the debate of plastic bags and whether plastic bags should be forbidden or not. Today many countries are banning plastic bags. In this case it is not because of high environmental impact from production of plastic packaging, however, the fact that many plastic bags end up in the oceans creating large problems for the sea life today and even more uncertain consequences for the future (Lewis, 2010).

4. Adoption of the 'polluter pays' principle. The Directive 94/62/EC on packaging and packaging waste (European Council, 1994) makes the producer responsible for recycling of packaging put on the market. Taxes on fossil fuels is another example.

3. A service perspective

The aim of this thesis is to increase knowledge about how packaging can contribute to a more sustainable development, to save nature and increase equity among people today and tomorrow. The main stakeholders involved in this were recognized to be the consumers, the businesses in food and packaging sectors and the governments that regulate the areas. To make improvements for a more sustainable development, all stakeholders have to be addressed and involved.

A better understanding of the individuals' interactions with packaging makes it easier to understand the environmental and social impact from the user phase and later develop improved business offers which reduce the environmental impact and improve social aspects. However, there is a need to recognize that businesses need also to earn money in the work for a sustainable development. A service perspective was used mainly to improve the understanding about the environmental aspects in consumer interactions with packaging, although this may constitute knowledge about economic gains (both reduction in use of resources or higher values to consumer) for business.

In the next section, a brief overview of some aspects regarding goods and services and sustainability research is presented.

3.1 Service and sustainable development

The service and sustainable development research has been focused mainly on the potential of environmental gains by replacement of goods by services. The research approach Product-Service-System (PSS) has been going on for more than ten years and it is a research concept where technology, sociology, goods and services are viewed together with environmental issues from a system perspective (Mont and Tukker, 2006). In a literature review by Baines et al. (2007) it was concluded that PSS involves both viewing goods and service and it is about the 'value in use'. The researchers have worked with "servicization" of products and the "productization" of goods (Baines et al., 2007). The research projects have been dominated by questions about ownership and about dematerialization.

When owned goods are replaced by renting, leasing or sharing goods, their design is supposed to be altered to make them, for example, more long-lasting (Mont, 2003). The increase of rent and lease options has been identified as having possibilities to foster sustainability, because if businesses focus on providing the service instead of goods, it is central to maintain the goods efficiently (Vargo and Lusch, 2008a). The development of a new strategy of non-ownership has also been examined from a service marketing perspective (Lovelock and Gummesson, 2004). It was observed that the marketing strategy in non-ownership is different from a marketing strategy with ownership and that the rent/share approaches offer new dimensions of the service reality (ibid.).

Some observations about the PSS-research: It has to a great extent been within the tradition of differentiating between goods and service. Many studies deal with dematerialization and change of ownership issues. The PSS -research has not influenced the general business to a large extent, perhaps because the concept comes from a design perspective and not a business perspective (Tukker and Tischner, 2006). There is now an awareness of the need to increase methods that understand the consumer and the 'value in use' (Baines et al., 2007). It has been concluded that goals for sustainable development are rare in PSS projects, even if that is generally assumed to be a goal (ibid.)

3.2 The service perspective

It is only in the last five to six years that the service research itself has developed away from the traditional way of describing service in relation to goods (Lovelock and Gummesson, 2004; Edvardsson et al 2005; Vargo and Lusch, 2004). Within service research, several authors recently have suggested that everything is service and consumers consume services no matter whether they actually buy goods or services (Vargo and Lusch, 2004; Grönroos, 2008). The ideas of moving away from 'goods versus services' thinking is developed in the Service Dominant Logic (SDL) (Vargo and Lusch, 2004; Vargo and Lusch, 2008b) and by the approach of service as a perspective (Edvardsson et al, 2005). Both approaches focus on what goods and services can do for the consumers. With this view it is not meaningful to define goods or services distinctly since the services and goods are related to each other and business's offerings are often a combination of both (Edvardsson et al. 2005; Vargo and

Lusch, 2008b). In order to understand service you need to understand the goods (Grönroos 2008b). SDL focuses highly on the consumer role, both as a co-producer and as the determiner of the value (Vargo and Lusch, 2004).

The role of consumer as a co-producer and that the value is experienced in use are essential in the sustainability context. If a better offer should be proposed, the businesses need to focus more on understanding the use-phase because that is where the value is perceived. This often includes collaboration and learning with consumers (Matting et al. 2004). When the value is understood, the aspects about the use of resources and the environmental impact from the use-phase can be understood. The service research with the focus on user provides valuable knowledge of behaviour that influences the total environmental outcome of an offer, if this perspective is included in the analysis.

3.3 The value of an offer

In order to understand what is essential for the consumer it is important to understand the use experience and the resources that are available in the consumer use context (Edvardsson et al. 2010). Cook et al. (2002) have explored a needs-based framework in order to understand customer delight, where the underlying premises are that humans are people first and consumers second. This distinction between people and consumers may play a significant role in the understanding about humans in the context of sustainable development. In the packaging for sustainable development, consumers act mainly as citizens when taking active part in different packaging recycling schemes and they are doing what is good for society/nature. In their judgments of the packaging offer, the consumers may for instance recognize if the package is easy to recycle, since consumers consider this attribute to be fairly important (Paper I, Table 2). Cook et al. (2002) considered more of core needs as security, fairness and esteem, in the attempts to better understand humans and try to move beyond the more traditional meet-expectations models by e.g. Zeithaml and Bitner (1997). It may be in these core needs that we can find the resemblances in the search for how to move into a more sustainable direction. Sebhatu (2010) suggests a value-based thinking to drive value creation towards efficiency.

3.4 Our approach of using the service perspective

Environmental analysis has often been done from the traditional goods-centred logic. The goods are the end products that are tangible. It is easier to measure the environmental impact from the production sites and the distribution chain than from the consumer phase which is individual and therefore can differ a lot. The more intangible characteristics an offer has, such as how information printed on a package is interpreted, the more crucial it is to understand the consumer preferences and the consumer actions. The environmental impact of the service process is often of high importance and should not be neglected. The energy use for heating old opera houses to provide a comfortable climate while watching theatre can be of high importance. An indicator of "eco-driving" in a car can influence the driving and the factual gas consumption. What students learn about environmental impact during education and how they may use this knowledge after graduation can be more important for the environmental impacts than used energy or paper consumption at a university.

We have experienced a large potential to use the user-centred focus to learn about consumer behaviour and how this influences resource utilization and environmental impact. One aspect is that our approach of using the service perspective follows the business intentions to move up in the value chain, by understanding the consumers and proposing higher values (Olsmats, 2002, Olsson 2005). It is often good to introduce new ideas from a perspective with which the receiver is already familiar (Ramsden, 1999). When using the service perspective to improve the environmental impact, this hopefully increases the chances of succeeding with this task within business. Consumer focus has been a goal for many businesses within packaging (Olsmats, 2002). Inclusion of information about the use of natural resources when the 'value in use' is discussed and decided upon may be a suitable course for further investigation.

The service perspective was also used by Annika Olsson (2005) for the transformations within organizations as to how they can learn and change in order to promote offers to the consumer with increased values.

Improving the consumer value, from the business perspective, has a direct environmental concern; because no matter how efficient and environmentally beneficial products might be that are placed in the shops, if the consumers do not buy them there will be an unnecessary environmental impact. Many product

innovations actually fail on the market (see e.g. Cooper, 2001; Hill and Jones, 2009)

3.5 Service perspective and packaging

Packaging has traditionally been seen as a product that holds, protects and informs about the product inside. Packaging should also help to sell the product (Prendergast and Pitt, 1996; Underwood et al, 2001). Later a packaging should add convenience for the consumer by e.g. being easy to open and reclose.

According to Löfgren (2006), the value that comes from packaging is not the package itself; it is the consumer experience of the total offer. The total offer of packaging is described as the product, the packaging and prerequisites for service, Figure 1.

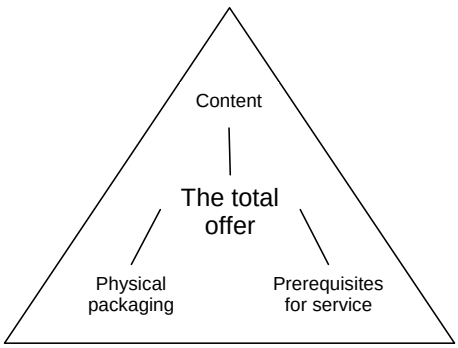

Figure 1: *The total offer from a packaging perspective (Adapted from Löfgren, 2005)*

Löfgren used the service perspective to focus packaging as 'doers' and he concluded that scientific publications on what the packaging does are rare (Löfgren, 2006). In the packaging context, the consumer experiences the quality of the total offer both at time of purchase and when using it. This was called the total offer of packaging in the first and second moments of truth (Löfgren, 2005; Löfgren et al., 2009). The first moment of truth is about getting the customer's attention in stores and to quickly communicate the benefits about the product; in the second moment of truth, the customer experiences the benefits of the offer (Löfgren, 2005). In the case of packaging, the second

moment of truth can occur a long time after purchase and occur many times since the content may not be consumed on one single occasion (Wansink, 1996; Löfgren et al., 2009). It is mainly in the second moment of truth that the prerequisites for services are changed into user processes (Edvardsson, 1997).

With a service perspective, both goods and the prerequisites for service need to be considered. The environmental analysis of packaging has traditionally been by analysis of the following value chain: raw material utilization, additives, energy use for materials, production and conversion, type of transportation and distances, recycling of packaging material. Such a value-chain approach is goods-dominated (Gummesson, 2008). The food has usually been analyzed in the same way, from a goods perspective. With a service perspective the environmental aspects that relate to the using phase and how consumers interact with the prerequisites for service may be understood and accounted for.

In this thesis the service perspective has been used mainly for understanding the consumer interaction with packaging in the second moment of truth and at an attribute level. This was done in order to understand how consumer behaviour influences the environmental impact however, also how the environmental impact may change when attributes are improved.

4. Packaging influence of food losses

In Paper I the environmental consequences of developing packaging according to consumer needs was explored. A study from Löfgren and Witell (2005) regarding consumer experience of packaging of everyday commodities was combined with a literature survey on environmental impact of packaging and of food. The literature survey showed that many environmental judgments on packaging do not consider the food it protects or the amount of food losses. This is remarkable since the packaging often constitutes only a small percentage of the total environmental impact in the food-packaging system (Hanssen, 1998). However, to my knowledge it is only in the last few years that there have been research projects that have demonstrated the large amount of food wastage in homes and in food institutions. The food loss amounts are somewhere between 15% and 30% of the bought food in Europe and USA (Kantor et al., 1997; Engström and Carlsson-Kanyama, 2004; Ventour, 2008; Quested and Johnson, 2009). Another explanation why the environmental impact of packaging itself has been focused is to reduce the waste amounts from packaging, according to the Directive on packaging and packaging waste (European Council, 1994).

In the study, it became clear that packaging influences food losses at the consumer in many different ways (Table 1).

Table 1: *Quality attributes of packaging that relates to food losses*

Technical assets	Ergonomic assets	Informative assets
Non-leakage	Easy to open	Best-before-date
Protection	Easy to empty completely	Declaration of content
Hygienic	Contains the right quantity	Instructions
Reseal-ability	Easy to portion	Appearance=content
Attractive and nice looking print	Facilitates correct storage	Aesthetically appealing

Several of the quality attributes that influence food losses were considered important by the consumers. If packaging designers want to improve the quality attributes in Table 2, most of the improvements were assumed to reduce the

amount of food losses. However it was difficult to see that improved *'attractive and nice looking print'* and *'aesthetically appealing'* could decrease losses. One possible scenario is that a higher attractiveness influence consumers to buy more than they need or things they don't like and therefore actually waste more of such products.

There are losses of food earlier in the distribution chain. These causes of food waste can come from environmental influences (e.g. humidity, temperature), biological influences (e.g. respiration, the food continues to change after harvest) or from socioeconomic influences (e.g. insufficient marketing or distribution) (Kader, 2005)

4.1 Increased customer satisfaction and reduction of environmental impact

From a business perspective it became obvious that there were possibilities to both increase customer satisfaction and decrease the environmental impact from the food-packaging system. The two attributes '*resealability*' and '*contains just the right quantity'* were considered attractive to the consumer and these can improve the consumer satisfaction if they are improved in a new packaging design. These attributes can make a difference to the total environmental impact in the usage situation. *'Resealability'* can make the food fresh for a longer time and reduce food waste. If consumers can buy the right quantity for their specific needs, e.g. different packaging sizes for different household sizes, it can decrease the amount of food that is wasted.

Since there were many connections between packaging design and food losses, the potential size of packaging related food waste was investigated (Paper IV). It became important to quantify the balance between decreases in environmental impact by reducing food losses against increases in environmental impact from more packaging material (Paper II, III).

5. Analysis of the environmental impact of packaging systems

Life Cycle Assessment (LCA) is a method where the environmental aspects and impacts of all of the included steps (from cradle to grave) for a goods or a service life cycle could be judged (ISO 14040-43). An LCA consists of three components, inventory, impact and improvement of a clearly defined system (Lindfors et al., 1995).

5.1 Packaging and LCA

The environmental impact of packaging has often been calculated for as a product (without the content or the consumer phase). Packaging is also often included in LCAs of food or other products. A schematic presentation of a food supply system, from agriculture to waste handling is illustrated in Figure 2. However, a majority of published LCAs of packaging or food does not include the consumer phase, or treat it by simplistic scenarios. LCAs of food-packaging systems are further described in Chapter 7.1-7.3

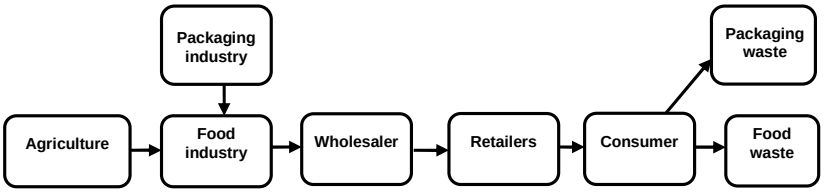

Figure 2: *Schematic presentation of the food supply system. Arrows represent transports.*

When data about packaging from different LCA-studies has been used in our studies it includes *primary* packaging (the consumer packaging), the *secondary* packaging (the packaging that is handled at wholesaler and retailer, where several consumer packaging make up a larger unit) and the *tertiary* packaging (the transport unit, secondary packaging on a pallet).

5.2 A lot of food is produced and wasted

There are indications that up to 50% of the produced food is wasted worldwide (Kader, 2005). As much as 30% of the bought food in Europe and USA is wasted by consumers (Kantor et al., 1997; Ventour, 2008; Quested and Johnson 2009; Fredriksen et al., 2010). This is a large and often unnecessary waste of the world's limited natural resources. As waste increases, the production of food and packaging material is larger than it would have been if consumers bought only as much as they needed.

What is seldom observed is that the amount of purchased and produced food increase in a non-linear fashion with increasing food losses. This become clear when the amount of eaten food is considered instead of purchased food;

*Eaten food = Purchased food – Purchased food * Loss fraction at consumers*

This means, for example, that if the food losses at consumer are 30%, the amount of purchased food is 43% higher than if there were no losses. Well worth considering… This fact is neglected in most LCAs, and makes it even more important to reduce food loss of items with high losses at consumer; examples of such products are fruit, vegetables and bread.

5.3 Environmental balance of food losses versus packaging

When new packaging is developed, the best environmental scenario is if the packaging is more resource efficient and at the same time provides better solutions that reduce food losses. However, if that is not possible the next best scenario is often to develop packaging that reduces amount of food losses even if the package has somewhat higher environmental impact. A mathematical model for calculating this balance was developed in Paper II and the balance was calculated by using LCA-data for five food items; beef, bread, cheese, ketchup and milk in Paper III.

The model includes food losses and the unit upon which calculations are based is '*eaten food*' (not '*purchased food*' as in many other LCAs). The used food supply system is shown in Figure 2. With LCA data that includes the consumer phase, the model can be used to calculate several comparisons, for example the change

of environmental impact (*E*) due to changes in food losses (*L*) and packaging (*P*), given the environmental impact of food item (*F*), waste management of packaging (W_P) and food waste (W) is known (Eqn 1).

$$\frac{E_2^i}{E_1^i} = \frac{1-L_1}{1-L_2} \frac{F^i + P_2^i + W_{P_2}^i + W^i}{F^i + P_1^i + W_{P_1}^i + W^i} \qquad \text{(Eqn 1)}$$

The environmental impact can be calculated for different environmental categories (i), as energy, climate change impact, eutrophication, etc. The environmental impact of eutrophication and acidification is dominated by agriculture and the impact from packaging is relatively smaller compared to the share in energy use and global warming impact. If the total energy decreases in a system with a new packaging design that reduces food losses, the global warming, eutrophication and acidification will decrease even more.

It is important to know about the different conditions for different products. Food items with high environmental impact and/or high waste level do motivate more effort in packaging development. Cheese is an item with high global warming impact, one kg of bought cheese contributes to about ten kg of carbon dioxide equivalents[6] (Berlin, 2002). Initiatives to reduce cheese losses by new packaging solutions are easy to motivate. If the goal is to decrease the global warming impact of cheese, and the amount of cheese losses is reduced by 5% (from an initial level of 10% cheese loss), the new packaging solution may increase more than ten times, compared to the existing packaging, and still result in a lower global warming impact from the food-packaging system (Paper III).

Bread has a lower global warming impact per kilo; however, there are higher amounts of losses. One kilo of bought bread contributes to less than one kg of carbon dioxide equivalents (Andersson, 1998). If the amount of bread losses is decreased by 5% (from an initial level of 20% bread loss), the new packaging solution may increase up to 2.5 times, compared to the existing packaging of bread, and still give a lower global warming impact from the food-packaging system (Paper III). If the packaging system (primary, secondary and tertiary

[6] Carbon dioxide equivalents (CO_2-equiv.)-"A metric measure used to compare the emissions from various greenhouse gases based upon their global warming potential" *(EPA, 2011)*

packaging) for one kilo of bread is reduced by 5% about 1g of carbon dioxide equivalents will be saved (Andersson, 1998), a development required by Directive 94/62/EC. If bread losses are reduced by 5%, about 30 g carbon dioxide equivalents will be saved, for this development there are still no Governmental requirements. The consumption of bread, viennoiserie, patisserie was 38.7 million tons in the EU 2006 (Gira, 2007). Small reductions of food losses can mean large environmental savings when the total consumption is considered.

5.4 Environmental effects of different waste handling options

For the total outcome of the environmental impact from a food-packaging system, the impact from the handling of both food and packaging waste is important (Paper II). About half of the amount of household waste (≈260 kg/household) in Europe ends up in landfill (EEA, 2008). If this is decomposed aerobically (with oxygen present) the carbon dioxide from production will be set free into the atmosphere. However large amounts are decomposed without oxygen present, under anaerobic conditions and during these conditions methane is produced. Methane influences the global warming[7] more than if carbon dioxide is released from the decomposition processes.

The environmental effects of food waste change the balance between the impacts from packaging and food. The possibilities are greater of motivating an increase in the environmental impact of packaging for reducing food losses, if food waste ends up in landfill or wastewater plants, which increases energy use. In cases where food waste can be recovered as energy and this energy is calculated to replace other energy sources the environmental potential to find new packaging solutions is somewhat lower.

If packaging waste ends up in landfill it causes some methane production, which increases the environmental impact and this means that the potential to find new packaging solutions with higher environmental impact decreases. If there is efficient packaging recycling, the possibilities are greater of motivating an increase in the environmental impact from packaging. "Different scenarios for bread, bread losses, and packaging changes are illustrated in Figure, 3.

[7] 1 kg of methane has about 25 times greater influence on global warming compared to 1 kg of carbon dioxide *(Cunningham and Saigo, 1997)*

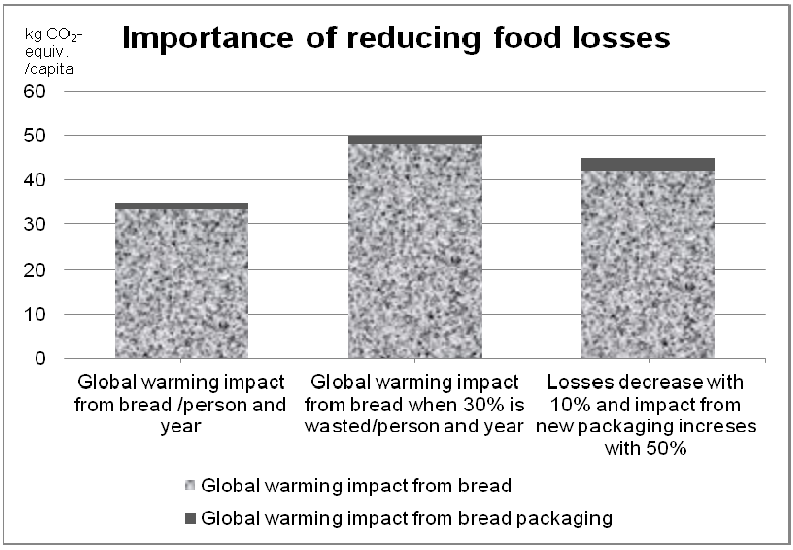

Figure 3: *The effect on global warming impact from different scenarios when developing new packaging that can reduce food losses*

For food items with low environmental impact, low waste levels and inefficient waste management of packaging, it can be better to accept food waste than to increase packaging.

6 Household food waste: behaviour and attitudes

We have some knowledge about why households waste food. Most of the studies have been done in the UK. About half of the wasted food in the UK was wasted because it was not used in time (Quested and Johnson, 2009). About 2/3 of families with children claim a lot of food waste depends on the children (wrap, 2007a). The reasons for food losses were; e.g., '*lack of plan*' or '*change of plans*', '*buying too much*', '*do not want to eat leftovers*' or '*do not know what to do with them*' or '*high sensitivity to food hygiene*' (Cox and Downing, 2007).

Packaging is a reason for food waste. In a Norwegian study, 15% of the consumers said that packaging was a main cause of food waste, and out of these 30% of the consumers stated that too large packaging is a reason for food waste (Fredriksen et al., 2010).

In paper IV, sixty-one Swedish families participated. The participants were asked to report the avoidable amount of waste food, i.e., food that at some point prior to disposal had been edible. They were instructed to measure, preferably weigh the amount of food waste for seven days and report in a diary, and the reasons for wasting (Paper IV). Thirty of the households had previously received education concerning various environmental issues in an environmental project called "MiljöVarDag" (i.e., Swedish for "Environmental Issues in Everyday Life"). The second group consisted of thirty-one households (henceforth called the reference group) who were considered to be ordinary however, committed households, although, without any known former environmental education. The household packaging related food losses were estimated to be 20% to 25% of the wasted food. The higher number is from the more environmentally educated group and the lower from the reference group. The households in this study wasted on average half of the amount relative to other studies, although there were differences between the two groups. It is therefore difficult to judge if this share of packaging related food waste is representative for other groups.

The reasons given for food waste from packaging were because packaging is '*difficult to empty*' '*too large packaging'* and waste due to '*best-before-date*'. In the packaging aspect category '*difficult to empty*' 3/4 came from yoghurt and sour milk in liquid packaging board, and 1/4 consisted of liquid margarine, jam, porridge, mayonnaise and soups which were packed in plastic, glass, fibre or

metal packaging. The environmentally educated households manage to empty or squeeze the packaging better and could use more of the content. They left an average of 63 g yoghurt and the reference group left about 100 g yoghurt in the packages.

The environmentally educated households wasted less food due to past "best before date". They wasted only half of the amount of prepared food, compared to the reference group. It is uncertain whether their food management planning or their behaviour with food at home is the reason for these differences. The environmentally educated households were more observant of packaging aspects in relation to food waste.

6.1 Attitudes to packaging

A questionnaire about different statements regarding attitudes to food waste, packaging and purchase habits were also posed to the respondents. They were asked to grade the statements from 1(do not agree at all), to 7(do fully agree), a Likert-scale[8], see example in Table 2.

Table 2: *Example from the questionnaire that was used in the analysis (Paper IV).*

Questionnaire

Example of questions that was used in the analysis
(Notice from 1 to 7 how you agree to the statement below)

	Do not agree at all						Do fully agree
1.6 What is your general opinion about packaging?							
a. They protect the content from grocery store to my home	1	2	3	4	5	6	7
b. They protect the content to make the food more durable.	1	2	3	4	5	6	7
c. They make my everyday life easier.	1	2	3	4	5	6	7
d. They are a waste of resources and should be minimised.	1	2	3	4	5	6	7
e. If I/we could choose, the packaging should be removed.	1	2	3	4	5	6	7

The environmentally educated households expressed a more negative attitude towards packaging. About 25% of these households agreed to a high extent (answering 6 or 7 on the scale) to the statement "*If I/we could choose, the packaging should be removed*" and about 15% of the households in the reference group agreed to a high extent. In the UK, between 75% and 90% of the consumers

[8] A scale used for measurement of individuals' attitudes to a topic. Developed by US psychologist Rensis Likert and described in his thesis, 1932 *(Oxford English Dictionary)*

agreed that discarded packaging is a greater environmental issue than food that has been thrown away (Cox and Downing, 2007; wrap, 2007a).

Why are environmentally conscious people negative towards packaging? The view of packaging as something 'bad' for the environment, which should be minimized, has hidden the more important focus of packaging optimization for a more comprehensive environmental approach (Svanes et al., 2010). Governments in Europe have focused on minimizing packaging waste (European Council, 1994). Businesses almost only market environmental packaging improvements when it is about packaging material reductions or increased use of renewable materials (e.g., Coca Cola Company, 2010; Guardian, 2009; Wal-Mart, 2011; Whole foods market, 2010). The directive and business communications illustrate to the consumer that packaging itself is what people should care about. There is still no European directive to reduce food waste, which signals that this is less important than packaging waste.

6.2 Purchasing habits influence food waste

Purchasing habits influenced the amount of food wastage. Households that noted that they purchased food more often wasted on average about 1.2 kg/household per week compared to about 2 kg/household per week from the households that noted purchase of food more seldom. The correlation between food waste and purchasing frequency was stronger in the reference group than in the environmentally educated group.

However, the consumer transport, which constitutes a significant part of the total transportation within the chain (Davis and Sonesson, 2007) will increase with higher purchase frequency. This identified environmental trade-off needs to be analyzed.

7 Packaging for sustainable development

You really can change the world if you care enough. Marian Wright Edelman

Sustainable development is a complex matter. In the area of packaging, sustainable development has often evolved from the environmental area and the social and economic issues have been added to the context. As mentioned earlier, LCA is a common method of studying environmental issues. In a sustainability context, it is important that LCA is applied with wide system boundaries (Klopffer, 2003). Many researchers have noticed the importance of a more holistic[9] perspective in packaging development , e. g. Prendergast and Pitt (1996), Twede and Parsons (1997), Johnsson (1998), Saghir and Jönson (2001), Svanes et al (2010). The reason for a more holistic approach is that there is a risk of sub-optimization if every stakeholder optimizes her/his part of the life cycle (Deming 1986; Deming 1994).

In Paper V some shortcomings are identified in the literature about packaging in the sustainable development context. First, the work is done from a business perspective, overlooking the institutional framework (policy and infrastructure issues) and especially the global issues (nature's carrying capacity, sharing resources and future generations). Second, the work is done without the effects of the users' behaviour.

In the context of sustainable packaging development, packaging research should be related to the main goals and principles of sustainable development. In Paper V, we suggest goals for a sustainable packaging development. Five system levels of the research are suggested, from packaging as an artefact to the global perspective, in order to structure the research. Each level is necessary for study. The goals and levels are presented below.

[9] Holistic is characterized by the tendency to perceive or produce wholes *(Oxford English Dictionary)*

7.1 The main goals of packaging for sustainable development

In Paper V three goals for packaging for sustainable development were proposed. The goals are in accordance with the main goals of sustainable development (Chapter 2).

- Packaging should help to reduce the total use of limited resources and to reduce the total environmental impact. A more efficient resource use increases the likelihood that more humans, today and tomorrow, can share the benefits of the resources.
- Packaging should improve the social conditions for those who handle and use the packaging, staff as well as consumers. Packaging should help to satisfy basic human needs, all over the world.
- Packaging that fulfils these conditions should be economically competitive, to remain in the market and influence the development.

In these goals, efficient use of resources, equity, global and economic perspectives are included. The goal of the economic dimension is subordinated to the other dimensions as they are the main components of sustainable development. However, it is important to include the economic dimension; both from a business perspective, and from the governmental perspective due to instruments of control (regulations, taxes, etc).

7.2 The first packaging-system level

In this first system level it is an analysis of the packaging itself; material, energy use, packaging production, transports and waste handling, (Figure 4).

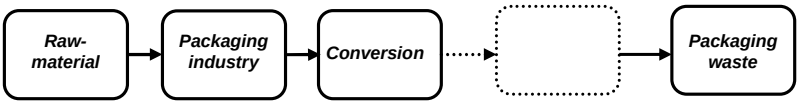

Figure 4: *The first packaging-system; packaging*

The different environmental impacts are analyzed. This can be done by using generic data from databases as in the study of coffee (De Monte et al., 2005) or by using site specific data as in a study of beer (Cordella et al., 2008). The consumer phase is often not included or treated by simple assumptions. The

LCA is done for a specific packaging or comparisons of different packaging solutions of packaging materials.

7.3 The second packaging-system level

In this second system level the content is added to the packaging system, (Figure 5).

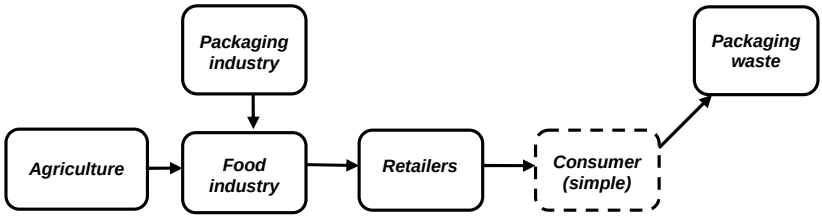

Figure 5: *The second packaging-system; food-packaging*

The focus here is more often an analysis of potential improvements of the product-packaging system. The physical packaging interactions with the food are considered, for example distribution efficiency. If product, packaging and logistics are analyzed as a system, improvements can be identified in the system that were not possible to discover if each part were optimized separately (Hellström and Saghir, 2007). The packaging design influences the environmental impact earlier in the distribution chain. The filling degrees of primary, secondary and tertiary packaging influence the possibility for efficient distribution.

The consumer phase is often not included in the analysis or treated by simple scenarios. For example, an LCA of food may include consumers' impact from driving to the retailer and/or from storing food in a refrigerator. How the consumers actually use the food, how they cook, how they portion, how they take care of leftovers are usually not included. Packaging waste is often accounted for by using mean-values from a country's recycling statistics. However, the packaging design is not assumed to influence the consumer behaviour and this can make a large difference if the LCA-results are used for packaging design decisions. In the first and second packaging-system levels, the social aspects are not included.

7.4 The third packaging-system level

In this third system level the product-packaging system includes the consumer phase, see Figure 6. Consumer behaviour can play a significant role for the environmental impact. If it is left outside the analysis, important environmental aspects are not accounted for. At this system level goods, packaging and the environmental aspects that relate to the using phase and consumer interactions with the food and packaging are accounted for.

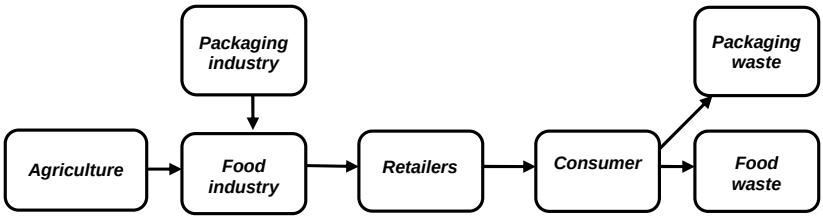

Figure 6: *The third packaging-system; food-packaging from a service perspective*

I list here some environmental aspects that relate to packaging and the consumer phase:

- **Minimize food waste**: Quantitative and qualitative protection of food, information about how to store, handle and take care of leftovers, appropriate amount of food for different household sizes, easy to portion attributes, and packaging which is easy to empty.
- **Reduce energy use**: Energy use can be reduced if the food packaging can be stored at room temperature compared with refrigerator or freezer. If the product is designed to be heated in a microwave instead of on a stove, energy can be saved.
- **Support efficient recycling**: Packaging that is easy to fold will take little space at home and during transport to and from recycling and save energy in transport. Information about how to recycle helps the consumer to do the right thing with the used packaging.

In the third packaging-system level, social conditions are included. Examples of social packaging attributes are '*easy to open'* and '*easy to grip',* because a large part of the population have reduced strength in their hands. In a study, about one-third of an elderly group said that they "frequently" or "very often" spilled

when opening packaging (Duizer et al 2008). This gives design implications that give trade-offs between improved function of packaging and environmental impact, e.g. introduction of better opening possibilities can add extra material to the package. Information provided on a package may influence the social implications, however, without trade-offs to environmental aspects. If information on how to store the product is printed on the package the content may last for a longer time, which reduce food waste.

There are social implications for people handling packaging along the supply chain. Examples of such packaging attributes can be 'easy to unpack onto retail shelves' and 're-loading secondary packaging at transport and storage'. Packaging that is easy to fold and recycle also has social implications both for users along the supply chain and consumers. The social aspects from individual handling of goods influence the working environment for labour and the time for loading and reloading. Time influences costs extensively; labour often represents the highest costs for distribution centres (Hellström and Saghir, 2007).

7.5 The fourth packaging-system level

In the fourth system level the institutional framework is handled. The interactions between the third packaging system level and stakeholders, such as organizations, society and its regulations, national infrastructures for recycling and transport systems are studied.

Today the environmental issues regarding packaging are regulated in the EU by the Directive on Packaging and Packaging Waste (European Council, 1994). The main goals of the directive are to reduce the amount of packaging material and make sure that the materials do not cause harm to the environment. The directive focuses on packaging as a product and gives only weak support for developing packaging that contributes to smaller food losses and reductions of the total environmental impact of the food-packaging system.

The way communities organise the recycling and how fees are administered will influence people's behaviour. If people have to travel a long distance to recycle packaging, they may choose not to be a part of recycling. Conversely if the

communities charge people high fees for their unsorted household waste, people will have a higher motivation to recycle. This means that the institutional framework and infrastructure will influence the social aspects and the environmental impact from the food-packaging system; these aspects need to be understood and considered.

7.6 The fifth packaging system level

In the fifth system level the global implications of sustainable development are studied. It is important to study how resources between people should be allocated in order to meet basic human needs today and in the future. This is the level where it must be understood how much resources there actually are on earth and how much of these can be prioritized to the packaging sector, if the needs for food, shelter and energy and transportation are considered. In this level we must consider how welfare can be more evenly distributed over the world; here with the means of packaging for sustainable development.

In order to move packaging development into a more sustainable direction all of the mentioned system levels need to be studied. It is essential that the goals for packaging for sustainable development, as well as the levels needed, are clearly understood among the participating stakeholders. 'Holistic' is sometimes used for every single one of the system levels. I believe it to be wise not to pretend that one's view is holistic; rather we have identified our contribution (Paper V) as a *more* holistic view of packaging for sustainable development.

8. Contributions

In this chapter some of the main contributions from our research are presented.

The knowledge about the environmental impact from the food-packaging in the consumer phase has increased from this thesis. In Paper I it was the first time where such a broad range of packaging functions was related to food losses. It was concluded that it can be possible to both increase consumer satisfaction, with improvements of packaging functions and to decrease the environmental impact by reducing food losses.

Within the packaging sector, some have discussed the optimum level of packaging material for protection of a product. However, to my knowledge no model for how to calculate such an optimum has been presented. The mathematical model that was developed in Paper II makes it possible to calculate solutions with minimum environmental impact, given data for the food-packaging system. These results revealed that development strategies for the 'best' packaging solution to reduce food losses by improved packaging vary substantially, for example with: *internal matters* e.g. the environmental impact ratio between the impact of food and impact of packaging and *external matters* e.g. waste handling of food and packaging. It was, however shown in Paper III that there are large potentials to reduce the environmental impact by developing packaging for reducing food losses.

Paper IV is to my knowledge the first study where packaging-related food waste at consumers has been measured. Significant amounts of food waste are related to packaging attributes. Earlier studies have been conducted by using questionnaires or interviews, where consumers have estimated their food losses in relation to packaging issues.

In Paper V we contribute with a synthesis of the goals and principles for sustainable development with the literature on "sustainable packaging". Earlier studies have often overlooked the overall goals and principles for sustainable development. The suggested approach focuses on the process forward and not defining the state of "sustainable packaging".

We have presented facts about critical weaknesses in the Directive 94/62/EC on Packaging and Packaging Waste, which focuses on packaging as 'goods' with low attention to the packaging attributes that reduce food losses.

In this thesis a more balanced view about packaging and its environmental implications has been presented. Packaging itself is not 'bad' or 'good' for the environment; however, the packaging attributes must be considered in a wide perspective.

It has been important for me to popularize the research and to contribute to change in society. There have been numerous reports in newspapers and magazines, several radio features and some TV features about the research over the years. We have had opportunities to speak at different conferences both for brand-owners and the packaging sector and have also been invited to governmental meetings and conferences.

Another contribution of this research is the build-up of new interdisciplinary research networks that can study the complexity of issues for sustainable development in the packaging context. I have initiated collaboration with the Service Research Center at Karlstad University, and the Division of Packaging Logistics, Department of Design Sciences at Lund University. The findings of this thesis have come out of this collaboration.

9 Some perspectives on my research

Sustainable-development research and food packaging research consist of many different disciplines and theoretical perspectives; *interdisciplinary research*. In the food-packaging area disciplines such as, environmental science, chemistry, microbiology, management, economics and social sciences are studied (Robertson, 2006; Ericksen, 2008). The different areas of knowledge and perspectives need to be integrated to solve the system-related issues between food and packaging and for how packaging can contribute to sustainable development.

Sustainable-development research is about handling issues in the local environment however, also how this can influence and be influenced by global conditions (Kates et al 2001). It is about the micro level, as to what individuals are doing with products at home, to the macro level, as to how much renewable resources can be utilized yearly without depleting the resources for future uses (ibid.). In sustainability science the time-scale needs to be considered. Many studies deal with today's conditions, however, it is necessary to consider the coming generations and their ability to support themselves. The science of sustainable development is 'caring' in its nature, 'caring' for the Earth and for its people (Kates, 2000; Bradshaw and Bekoff, 2001; McMichael et al., 2003). This means that the scientists within this research often start a research process because of their concern about human conditions and with a goal to help society to move into a more sustainable state (Kates, 2000.). One of the most important foundations is that work for sustainability needs to be integrative; it has to build bridges between areas of knowledge (e.g. biology, management, energy), geographical scales (both local and global conditions), and between people working with theoretical and/or practical issues (Gibson et al., 2000; Kates et al., 2001; Clark and Dickson, 2003; Schoot Uiterkamp and Vlek, 2007).

In a report from the US National Academy of Science (2005) the following definition of *interdisciplinary research* is presented.

> "Interdisciplinary research (IDR) is a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and or theories from more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or field of research practice."

9.1 Quantitative and qualitative research

Papers II and III are quantitative studies, whereas Papers I and V are based on the qualitative method. Paper IV is based on both quantitative and qualitative methods. To characterize research approaches as quantitative or qualitative is common within social science (Bryman, 2004). Both approaches can be informative in the search for answers to research questions; they are complementary rather than rival methods (Tashakkori and Teddlie, 1998) In the early stages of research it is often suitable with qualitative research (Bryman 1984). Some differences between the two approaches are presented in Table 3, in which a third paradigm[10], pragmatism is presented.

Table 3: *Comparison of three different paradigms (Adopted from Tashakkori and Teddlie, 1998, page 23)*

Paradigm	**Positivism**	**Pragmatism**	**Constructivism**
Methods	Quantitative	Quantitative+Qualitative	Qualitative
Logic	Deductive	Deductive+Inductive	Inductive
Epistemology	Objective point of view	Objective and subjective points of view	Subjective point of view

The natural sciences have more of a positivistic tradition, whereas social and behavioural sciences have a more constructivistic tradition (Tashakkori and Teddlie, 1998). Pragmatism is an approach where both positivistic and constructivistic traditions are used. In pragmatism the researcher agrees that there is an external reality and that there are no absolute truths (ibid.). A practical way of conducting research is to let the question decide which methods are most applicable. Pragmatism rejects the either-or ways but can embrace both points of views (ibid.). Pragmatics believe that values of people play a large role when drawing conclusions from research, however, they are not very concerned about that fact (ibid.) There are indications that methodological pluralism and the use of mixed methods may produce more robust research than research where only one method is used (Johnson and Onwuegbuzie, 2004).

[10] "Paradigm is made up of the general theoretical assumptions and laws and techniques for their application that the members of a particular scientific community adopt" (Chalmers, 1999)

I use a pragmatic way of conducting research, in line with the multidisciplinary and 'caring' research of sustainable development. Many of the studies in my thesis are exploratory as they seek to give new perspectives and results for understanding the role of packaging and its contribution to sustainable development. In a pure social-sciences context my approach may appear naïve at this stage, however, this integration of knowledge from different areas can be carried further. Most of my earlier learning processes have been within the natural sciences and this thesis is put forward within Environmental and Energy Systems.

The empirical material of this thesis, Papers I-IV, all comes from Sweden. Even if the ambition is to view and study packaging from a sustainable development context, which signifies the global perspective, the results and discussion in Paper V are still from a Swedish/European perspective. The perspectives on goal, learning and policy making are viewed with a Swedish pre-understanding of how things work. This social and cultural context has most certainly influenced our discussions.

10 Future research

"We can't just sit around waiting for the global solution" Elinor Ostrom

Despite the number of eco-design tools that has been developed (Baumann et al., 2002; Byggeth and Hochschorner, 2006), roadmaps for sustainable development (Waage et al., 2005; Waage, 2007) and the many studies about packaging and sustainable development (Svanes et al, 2010) there is a general lack of reflection about 'how' to reach sustainable development. The studies are often "technically" oriented. The methods are developed to help designers and product-developers to sort and prioritise among a large variety of issues. However, the likelihood that the methods actually will be used is seldom discussed. It is important to increase knowledge about how to change the progress into a more sustainable development.

No stakeholder can do sustainable development on its own and collaborations are therefore needed. The main stakeholders involved in the food-packaging system are presented in Figure 7.

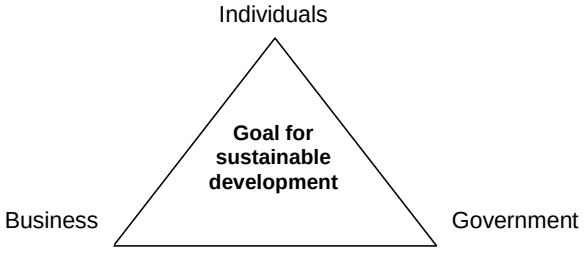

Figure 7: *Main stakeholders in packaging for sustainable development*

Governments cannot move far ahead of the people because they will not be re-elected. If governments move far ahead of other countries they will risk weakening the competitiveness of their own country's businesses. Business on the other hand cannot be far ahead of where the consumers are. Consumers need to accept the possibility that a better product (in a sustainability context) may be more expensive. If consumers reject those products and buy the cheaper ones from competitors with lower consideration to environment and working conditions then the businesses that 'care' more will be outrivalled.

Consumers need assurance that their 'sustainability'-money provides for a more sustainable development. Businesses that provide goods or services with higher values for nature, humans and fairness, need credible ways to communicate this to the consumers. Fair trade labels, EU Eco-label Flower and the Nordic Swan Eco-label are examples of trustworthy product communication. For packaging, this type of communication is missing. If it is to be meaningful with this type of consumer labelling for packaging, what can it look like?

It is important to identify the stakeholders that can promote packaging for a sustainable development in the present situation and what must change in order for the development to improve faster. There is a need to learn more about the circumstances for the ***power situation*** – who can, who want to and who are allowed to influence the development? An actor with power has the right structures and resources, the strategies to mobilize and the willingness to do so (Avelino and Rotmans, 2011). The retailer is found to have power in the food-packaging supply chain (Beckeman and Olsson 2011). An earlier study within the paper packaging sector showed that each actor was fighting to optimise their own part (Olsson and Györei, 2002). The packaging development often comes in late in core product development (Klevås, 2005) and food manufacturers seem to develop products in house, (Beckeman and Olsson, 2011b). Who actually has the necessary knowledge and power to act within the food-packaging supply chain today and promote packaging for a sustainable development? What are the consequences if there is no obvious actor with sufficient power?

Within this research-area there is a need to deepen the understanding about the packaging attributes that can be improved in order to reduce food losses in the life cycle of food-packaging. This will require, both methodologically and theoretically, reflections and developments. More knowledge is required about the users (in the supply chain and the end-consumers), their needs and behaviour. It is also important to find out how the consumers value such changes. I want to study further the packaging attributes that influence food losses in households and learn about different types of households. There is a need to increase knowledge about how consumer behaviour and attitudes can be influenced by new packaging designs, information and other policy instruments.

Within the theory for the service perspective there are more implications for sustainable development on which to elaborate; for example, study the consumer phase to identify the possible win-win situations (for nature and consumer), and study pros and cons of improved participation (one of the principles for sustainable development) by consumer involvements.

I want to widen the perspectives, and study the needs of more developing countries, for new dimensions for the research of packaging for sustainable development.

11 Closing remarks

During these years of research I have become impressed with the quality and depth that are presented about sustainable development in research today, however, I am also depressed about the fact that this knowledge is not considered to any significant extent. I do believe that most people would agree that they want their children to have a fair chance of food, water, shelter, love and freedom in the future; however, too many people act as if they do not care about the future generations. Why is it like this? How can we change the development? There are many questions regarding sustainable development that need to be addressed in research and society in the coming years. I find the research about happiness very interesting for a more sustainable society – a society that values more time with the one you love, less stress and less materialistic "happiness".

If my thesis somehow can influence the involved stakeholders or if other researchers can find inspiration into new questions or answers in this matter, I will be happy.

For me, this work has only begun.

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Food Packaging for Sustainable Development

There are indications that up to 50% of the food produced in the world is wasted. Wasting food is an inefficient way of using nature's limited resources. Food waste is also an ethical problem since many people around the world do not have enough food. This thesis has increased the knowledge about the consumer interaction with packaging and how that influences the environmental impact from the food-packaging system. Many of the services that packaging provides, especially for reducing food losses, are important for the environmental impact of the food-packaging system. Packaging can be designed to mutually increase consumer value and reduce food losses. One conclusion is that packaging should be analyzed together with its content and with knowledge about the consumer behaviour. The 'old' way of viewing packaging as an isolated artefact and focusing only on material and recycling issues, can give environmental sub-optimisations and also reduce the potential of developing better 'value' for the consumer. The European Directive on packaging should better recognize the services that packaging provide for reduction of food waste.

"Thank you for drafting this thought-provoking research".

Anonymous reviewer Paper I

"Excellent work. Refreshing to see a scientific paper considering product losses as the significant impact on the environment that they can be".

Anonymous reviewer Paper II.

"...on a well-written paper with very interesting and important factual content"

Anonymous reviewer 1, Paper III.

"This is a very interesting paper, where the author in a good way approaches an important part of food LCA and sustainability of food systems"

Anonymous reviewer 2, Paper III.

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