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Environmental Impacts of Electronic Media: A Comparison of a Magazine's Tablet and Print Editions

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Abstract

The aim of this thesis is to assess potential environmental impacts of electronic media distribution and consumption—from a life cycle perspective—as compared to those of print media.

The thesis consists of a cover essay and two papers appended at the end of the thesis. The cover essay summarizes the papers and puts them in context. The main objectives of the thesis are twofold: to assess potential environmental impacts of production and consumption of tablet editions of magazines from a life cycle perspective (Paper I), and to compare potential environmental impacts of a magazine's print edition with that of its tablet edition (Paper II).

The thesis examines the following specific research questions: (1) What are the main environmental impacts of print and tablet editions? (2) Which activities are giving rise to the main environmental impacts of the print and tablet editions? (3) What are the key factors influencing these impacts? (4) What are major data gaps and uncertainties?

Based on the present assessment, it is clear that for the print magazine, pulp and paper production is the principal cause of most of the potential environmental impacts. For this reason, the use of recycled paper, rather than virgin fiber, in newsprint production may considerably offset environmental impacts.

For the tablet edition, the content production dominates the potential environmental impacts when readers are few. This appears to be the case in an emerging state of the magazine, but with distribution of more media products to smaller groups of people, this may persist for "mature" products as well. As the number of tablet readers grows, more of the environmental impact of the is due to manufacturing of the device and electronic distribution. However, content production may still be a major factor, depending on the specific environmental impacts studied.

Keywords: electronic media, tablet computer, print media, magazine, information and communication technology (ICT), Internet, energy use, environmental impacts, life cycle assessment (LCA).

Acknowledgements

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This thesis would not have been possible without the camaraderie of my colleagues at fms (the Division for Environmental Strategies Research) and CESC, who have created an intellectually stimulating, supportive atmosphere, and a home away from home. Cross-disciplinary conversations, a collegial spirit, "fika" with cakes, group songs, lunches, and museum outings have shaped my work and my joyful time here in Stockholm! Tack så mycket!

On a personal note, I would also like to thank my mother, father, and three sisters, who have supported me during my studies in Sweden with their frequent phone calls. Həmişə sağ səlamət olasuz!

Finally, I am grateful to my beloved wife, Margaret, who proofread sections and, in support of my research, composed a song about LCA.

Mohammad Ahmadi Achachlouei
Stockholm, February 2013

List of appended papers and other publications

APPENDED PAPERS

Paper I — Achachlouei, M. A., Moberg, Å. & Hochschorner E. Environmental life-cycle assessment of a magazine—Part 1: Tablet edition. Submitted to *Journal of Industrial Ecology*.

Paper II — Achachlouei, M. A. & Moberg, Å. Environmental life-cycle assessment of a magazine—Part 2: A comparison of print and tablet editions. Submitted to *Journal of Industrial Ecology*.

Comment on co-authored papers:

Mohammad Ahmadi Achachlouei was responsible for data collection, modeling and writing the main part of Papers I-II.

OTHER PUBLICATIONS

Achachlouei, M. A., Moberg, Å. & Hochschorner E., 2013. Climate change impact of electronic media solutions: Case study of the tablet edition of a magazine. In the 1st International Conference on ICT for Sustainability (ICT4S 2013). ETH, Zurich.

Achachlouei, M. A. & Moberg, Å., 2012. Carbon and ecological footprints of a magazine: print vs. tablet editions. In the 18th SETAC Europe LCA Case Study Symposium. Copenhagen (poster presentation)

Picha, M., Achachlouei, M. A. & Moberg, Å., 2012. Magazine Publishing: Editorial Process Structure and Environmental Impact—A Case Study. In The 64th Annual Conference of the Technical Association of the Graphic Arts (TAGA). Jacksonville, Florida.

Achachlouei, M. A. & Moberg Å., A systematic review of energy and environmental assessments on electronic distribution of media. In preparation to be submitted to *International Journal of Life Cycle Assessment*.

Abbreviations

AOX	Adsorbable organically bound halogens
CESC	Centre for Sustainable Communications
COD	Chemical oxygen demand
DSLAM	Digital Subscriber Line Access Multiplexer
EIA	Environmental Impact Assessment
EPD	Environmental Product Declaration
GHG	Greenhouse Gas
ICT	Information and Communication Technology
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
SETAC	Society of Environmental Toxicology and Chemistry
TSP	Total Suspended Particulate

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1. Introduction

1.1. Background

The media sector is experiencing considerable changes, new ways of distributing content is being developed, and new devices are emerging at a high speed. The amount of time the average Swedish person spends on media has changed little during the last 10-20 years (Nordicom-Sverige 2011a), but the choices of media products have increased, and the younger generations in particular tend to increasingly spend their time on new electronic media (Nordicom-Sverige 2011b).

Electronic media, mainly due to the dematerializing advantage[1] of information and communication technology (ICT), appear to be more environmentally sound than, for example, traditional paper-based media. However, several studies on the environmental impacts of ICT and the internet have found both positive and negative impacts of production and consumption of ICT-based services (Berkhout and Hertin 2004; Hilty et al. 2006; Williams 2011).

The present thesis contributes to the environmental assessments of electronic media by investigating potential environmental impacts of the tablet edition of a magazine as compared to the print edition.

Investigating the effects of the development, diffusion and use of ICT on the environment, Berkhout and Hertin (2004) proposed three types of effects to analyze positive and negative impacts of ICT (see Table 1). These three types of effects were also examined in other studies. Hilty et al. (2006), for example, refers to them as first-order or primary effects, second-order or secondary effects, and third-order or tertiary effects (see Table 1).

Table 1. Impacts of ICT on the environment (Berkhout and Hertin 2004)

	Positive impacts	Negative impacts
Direct effects “first order”	-	Environmental impacts of production, use and disposal of ICTs (e.g. electronic waste)
Indirect effects “second order”	Improved efficiency, de-materialization and virtualization, detection and, monitoring of environmental change (e.g. intelligent logistics, electronic directories, environmental sensors)	Falling prices for resource inputs, proliferation of ‘intelligent’ devices, partial substitution (e.g. e-shopping as well as private shopping trips)
Structural and behavioral effects “third order”	Structural and life style transitions (e.g. growth of ‘light’ industries, green consumerism) shift from an industrial economy towards a service economy	Stimulating growth and re-materialization (e.g. growth of long-distance travel) Rebound effects

[1] “Moving bits instead of atoms is always less energy-intensive and environmentally damaging.” (Weber et al. 2010)

Plepys (2002) examined two categories of environmental impacts from ICT: first, those associated with the life cycle of ICT hardware, and second, those associated with the way ICT applications are used. Borrowing the concept from the energy sector, Plepys pointed to the rebound effects of ICT, which could be considered third-order negative impacts as described in Table 1.

Previous studies on energy use and environmental impacts of print and electronic media have shown there is no one answer as to which type of product is preferable from an environmental standpoint (Enroth 2009; Hischier and Reichart 2003; Kronqvist et al. 2010; Moberg et al. 2010; Moberg et al. 2011). These studies include media such as daily newspapers, novels, scholarly books, magazines, as well as electronic versions read from desktop computers, except for the studies on books and newspapers (Moberg et al. 2011 and Moberg et al. 2010) where e-ink tablet devices (e-readers) were studied. The previous studies employ a life cycle approach, yet content production has only been estimated or has not been included at all.

Both print and electronic versions of a typical Swedish magazine were assessed in a prior study (Kronqvist et al. 2010). In that study, however, the electronic version was read from a desktop computer, not from a tablet. Kronqvist and colleagues (2010) found the climate impacts of the print and electronic versions were of the same order of magnitude. They found further that user practices were of importance for the resulting environmental impacts. User practices are highlighted in other comparative environmental assessments of media products, e.g., Moberg et al. (2011).

When comparing ICT-based solutions with their conventional counterparts, in order to avoid shifting problems from one stage and/or region to another, it is best to conduct a full life cycle assessment for a well-defined function of the products being compared (Weber et al. 2010).

The development of new electronic devices is rapid and boundless. New tablet devices are less energy-demanding than computers, and the environmental impacts related to their manufacture can be assumed to be generally lower. It is therefore of interest to learn more about the possibilities for better environmental performance for media on tablets.

To complement the studies heretofore conducted and to learn more about the environmental impacts of print and electronic media, this thesis assesses the Swedish interior design magazine *Sköna Hem* in print and tablet versions, the latter of which is read from a tablet with an LCD screen, the most common type of tablet today. Further, the present study looks in more details at content production than have previous assessments.

1.2. Aims and delimitations of the thesis

The main aim of this thesis was to assess potential environmental impacts of electronic media distribution and consumption—from a life-cycle perspective—in comparison with printed media.

The main objectives of the Papers included in the thesis were:

- to assess potential environmental impacts of production and consumption of magazines on tablets from a life cycle perspective (Paper I),
- to compare potential environmental impacts of a print edition of a magazine with that of its tablet edition (Paper II),

The specific research questions examined in the thesis were as follows:

- What are the main environmental impacts for both print and tablet editions?
- Which activities are giving rise to the main environmental impacts for both print and tablet editions?
- What are the key factors influencing these impacts?
- What are major data gaps and uncertainties?

1.3. Outline of the thesis

The thesis consists of this cover essay and the two Papers appended at the end of the thesis. The cover essay serves the purpose of summarizing the Papers and putting them into context. In Chapter 1 the background, overall aim of the thesis, and specific objectives of the appended papers are described. Chapter 2 focuses on methodological aspects. It reflects on and elaborates the scientific context of the research conducted in the thesis. The results of the respective Papers are summarized in Chapter 3. Analyzing and discussing the results of the Papers, Chapter 4 summarizes the contribution of each paper to the overall aim of the thesis, discusses limitations the research, and provides proposals for future research. Finally, Chapter 6 closes the cover essay with a presentation of conclusions.

2. Method

2.1. Life cycle assessment

Both Paper I and II employed the methodology of life cycle assessment as described in the standard documents, ISO 14040 and ISO 14044 (ISO 2006a; ISO 2006b), and the software SimaPro 7.2.3 (PRé Consultants 2011). Life cycle assessment is an "environmental systems analysis tool" (Finnveden 2000) used to assess the potential environmental impacts and resources consumed throughout a product's life cycle, from raw material extraction, via production and use phases, to waste management (ISO 2006a).

LCA, as shown in Figure 1, is performed in the four phases: definition of goal and scope, inventory analysis (definition of the product system, collection of data and calculations of inputs and outputs), impact assessment (including selection of impact categories and classification, selection of characterization methods and characterization, and the optional phases of normalization, grouping and weighting) and interpretation (ISO 2006a; ISO 2006b). This is an iterative process, during which it is possible to go back to earlier phases and improve the analysis.

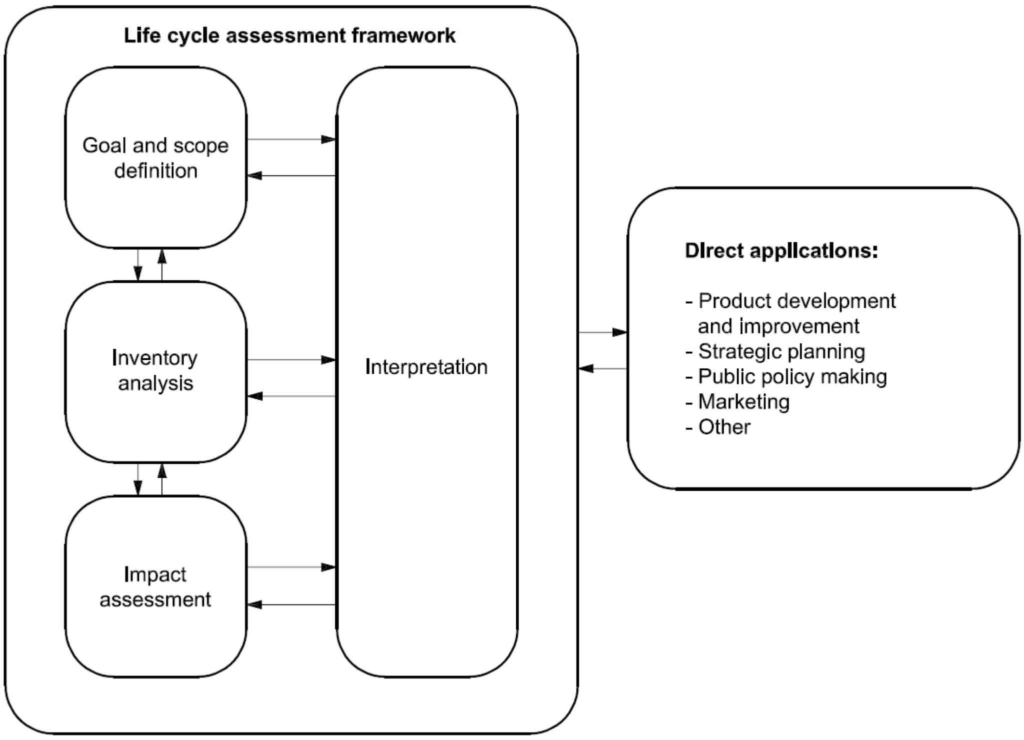


Figure 1. Phases of an LCA (ISO 2006a)

The development of LCA dates back to the late 1960s and early 1970s (Guinée et al. 2011). In their review of the past of LCA, Guinée et al. (2011) point to an unpublished study in 1969 on different beverage containers (of the Coca Cola Company) as one of the first studies "quantifying the resource requirements, emission loadings, and waste flows."

The scientific foundations of the LCA method have been discussed, mainly in the mid and late 1990s. For example, considering LCA a "decision support tool" and discussing the role of value judgments in LCA, Hertwich et al. (2000) concluded that "[e]ven if, due to the presence of normative elements, LCA is not a strictly scientific tool, LCA can still be objective." Employing experiences from practical LCA studies together with conclusions from theory of science, Finnveden (2000) evaluated the potential and limitations of life cycle assessment and environmental systems analysis tools in general. Critiquing the metaphorical basis of LCA, Ayres (2004) pointed to the weaknesses in LCA method originating from the analogy between nature and industry, which is embedded in LCA.

2.2. Impact categories

The chosen methods to model the results are classification and characterization with the Dutch method ReCiPe08 Midpoint (H) (Goedkoop et al. 2009) and cumulative exergy and energy demand (Frischknecht et al. 2007a; Bösch et al. 2006). ReCiPe Midpoint (H) version 1.06, includes 18 impact categories. Of these, only results from categories with sufficient underlying data for analyzing them are presented in this report. For both the electronic and print magazine these categories are considered to be

- Climate change
- Photochemical oxidant formation
- Particulate matter formation
- Terrestrial acidification
- Freshwater eutrophication
- Marine eutrophication
- Fossil depletion
- Metal depletion

For the tablet magazine somewhat more data related to toxicity was provided. Therefore results for the tablet version are also presented for the categories listed below, even though results for toxicity is always uncertain and should be carefully interpreted:

- Human toxicity
- Terrestrial ecotoxicity
- Freshwater ecotoxicity
- Marine ecotoxicity

Results are also presented as Cumulative energy and exergy demand for both the print and tablet version.

Cumulative energy demand (CED) investigates the primary energy used through a life cycle. It includes direct use as well as the indirect use of renewable and non-renewable resources (Frischknecht et al. 2007a).

Cumulative exergy demand (CExD) assesses the quality of energy demand and is the sum of exergy of all resources required to provide a process or product. The exergy of a resource is the minimal work necessary to form the resource or for the maximally obtainable amount of work when bringing the resource's components to their most common state in the natural environment (Bösch et al. 2006).

Besides traditional energy resources (such as fuels and renewable energy sources), the cumulative exergy demand also includes the exergy of materials. This describes the minimum energy that is required to produce the resource or maximum energy that can be extracted from the resource. Also freshwater is a resource that has an exergy content since it requires energy to produce it from seawater. The characterization method for CExD implemented in SimaPro, which is directly taken from Ecoinvent 2.0 (Bösch et al. 2006), was slightly modified to only consider water resources which are affected by processes in the system. This meant water passing through turbines in hydropower plants were not assumed to result in a decrease in exergy and the characterization value for the process "Water, turbine use, unspecified natural origin" was set to zero. This is because the water is still freshwater after passing the turbine, and we argue that this is not an exergy loss then.

2.3. Scope and functional units

The complete life cycle of each system—print and tablet magazine systems in Papers I&II—was covered, from extraction of raw materials and manufacturing to distribution, use, and waste management.

The functional unit is the definition of the benefit provided by the product system and gives a reference to which the inputs and outputs can be related. For the study presented in Papers I and II, the basic functional unit is defined as:

- One reader's use of one copy of *Sköna Hem*'s print and tablet version respectively, in 2010.

Previous comparative studies on media products have shown that the functional unit choice is of great importance on results of environmental performance (Hischier and Reichart 2003). Thus in this study we also present results using two other functional units:

- One hour of reading *Sköna Hem*'s print and tablet version respectively, in 2010.
- One copy of *Sköna Hem*'s print and tablet version respectively, in 2010.

2.4. Data collection and data sources

A comprehensive quantitative LCA is normally performed using a software tool for LCA. Such tools often include databases that can be used in the inventory analysis. In the LCA presented in Papers I and II, SimaPro 7.2.3 and the format and data categories therein were used.

Data were primarily chosen from actors in the supply chain of the product studied—For example, data from the environmental product declarations (EPDs) published by the paper production company and the Swedish postal services (Posten) were also used.

When this was not possible, data were taken from the Ecoinvent 2.2 database (Frischknecht and Rebitzer 2005).

2.5. Allocation procedures

In their survey of unresolved problems in life cycle assessment (LCA), Reap et al. (2008) see the allocation problem as one of the most controversial issues of LCA. Allocation can be defined as the procedure of partitioning inputs and outputs (or environmental burdens) of a multifunction process or a product system over its multiple functions or products (Suh et al. 2010). A methodological allocation problem arises in the LCA when a multifunction process fulfills one or more functions for the product life cycle investigated and a different function, or set of functions, for other products. Three types of allocation situations/problems can be considered: multi-output processes, multi-input process, and open-loop recycling (Ekvall and Finnveden 2001; Guinée et al. 1993).

Two principles of solving the allocation situations/problems are as follows (Guinée et al (1993), as cited in Ekvall and Finnveden (2001)):

1. Avoiding the allocation through: (i) system expansion (may also be labeled as "substitution," or "avoided"), (ii) more detailed study through division of the multifunction process into sub-processes, and collection of separate data for each sub-process.
2. Making an allocation (partitioning) in proportion to physical/non-physical properties of functions or products. Examples of these properties are mass, energy, economic value, information, time, etc.

A discussion of the allocation approaches applied in the thesis will be presented later in this cover essay.

2.6. Two tablet editions: emerging vs. mature

In the present study both *emerging* and *mature* versions of the tablet edition were studied. The tablet edition in its current *emerging* state means that it is currently not a mature product and that the number of copies and reading time per copy are low compared with those of the print edition (see Table 2).

The impacts of a potential future, more *mature*, version of the tablet edition were also examined. In the latter scenario the number of copies was increased so that it comprised half the current print edition. The reading time per copy was increased to the same level as for the current print version (see Table 2).

Table 2. parameters for both versions of the tablet edition

Parameters	Print edition	Tablet edition		Units
		Emerging	Mature	
Number of readers per copy	4.4	1	1	readers/copy
Reading time	41	9	41	minutes/reader and copy
Number of copies sold	1 307 000	2 212	653 500	copies (downloads)/year
Overall use time of tablet	-	14	14	hours/week (life time: 3 yrs)
Size of the copy	184 pages	163 (MB)	163 (MB)	pages/copy, or MB/copy

3. Results

3.1. Tablet edition

Results for the tablet edition is presented in Figure 2 and Figure 3. The results of the study indicate that the potential environmental impacts of the tablet edition of the magazine differ considerably between its emerging and mature versions (Figure 3). In the former the content production is the major reason for impact. This is due to the tablet-specific content production activities' environmental impacts being split on so few readers. With major changes in the media sector, which may lead to lower costs for publishers, related to the distribution and electronic devices replacing print on paper, it may become economically feasible to produce content for a smaller number of copies. In that case, content production may rise as a major reason for environmental impacts of media consumed on multi-purpose and energy-efficient devices.

For the mature version of the tablet edition, as studied here, the potential environmental impacts are related to the content production, electronic distribution and the tablet itself.

The sensitivity analyses further illustrate that the overall number of readers for the tablet edition are crucial to the resulting potential environmental impacts per reader. The electricity mix used in the processes of the products' systems may also significantly affect the resulting environmental impacts as well as the total use time of the tablet during its service life.

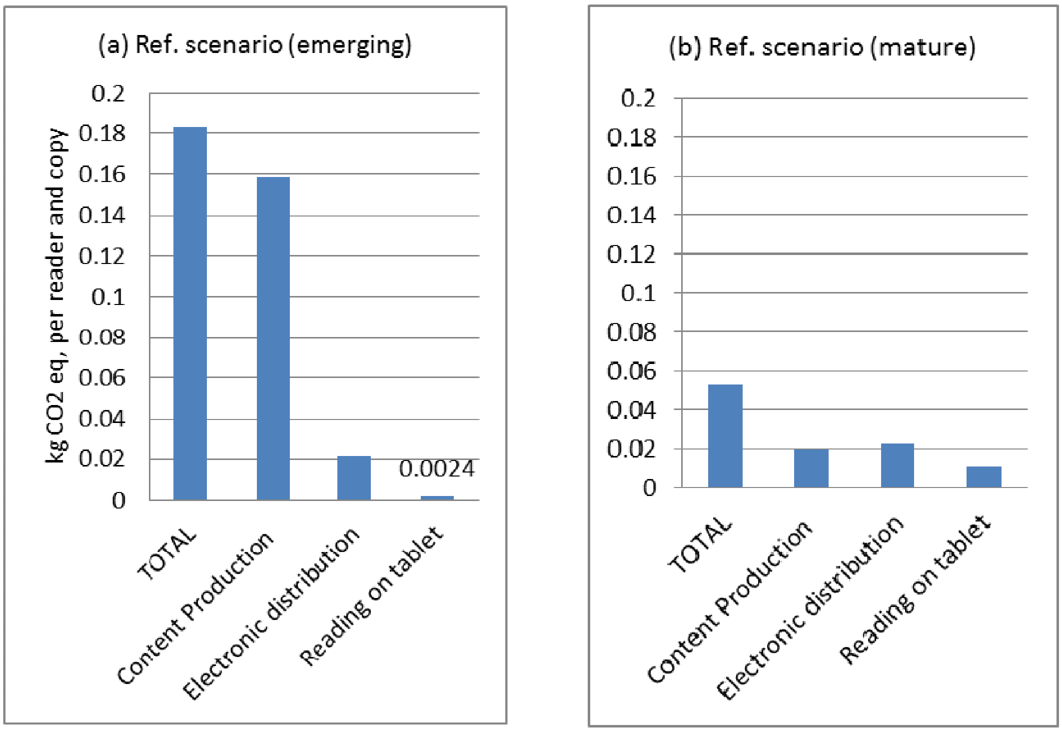
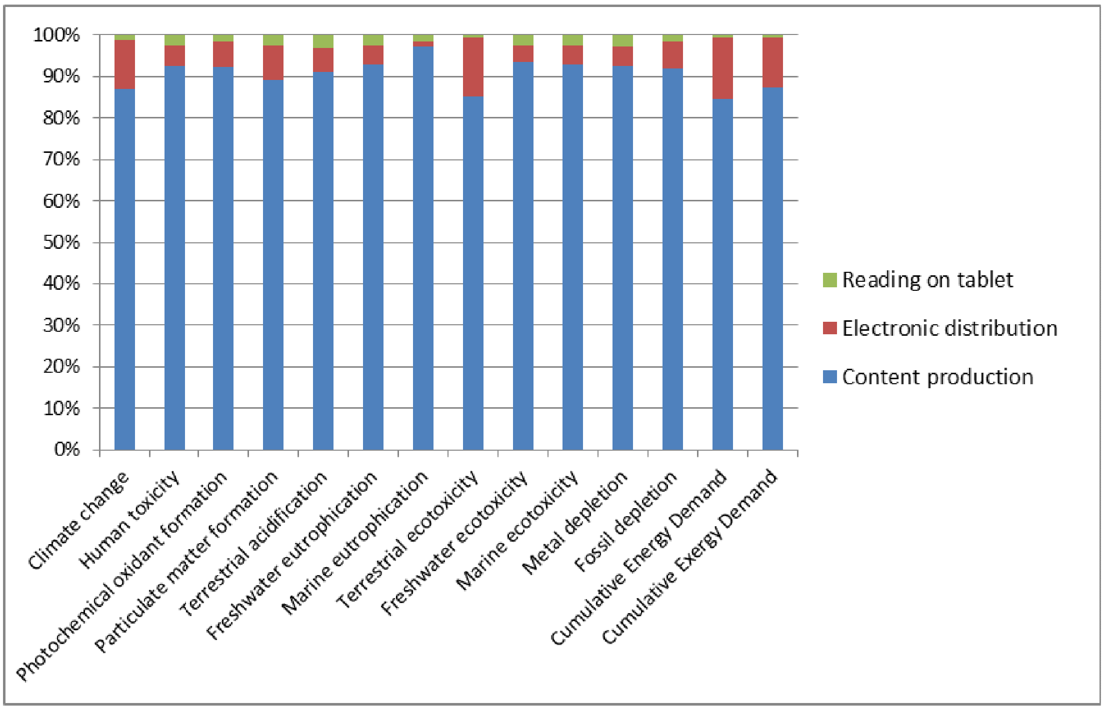
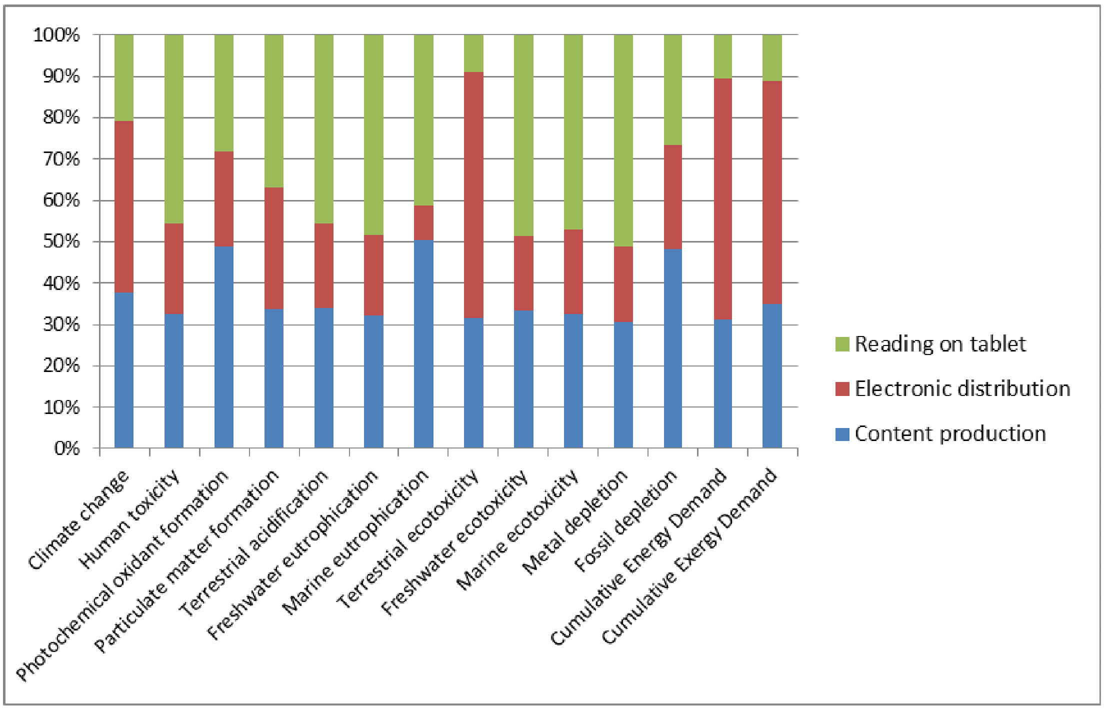


Figure 2. The tablet magazine climate change impact in the reference scenario (per reader of a copy). (Diagram from Paper I)



(a) Emerging version (current 2010)



(b) Mature version (possible future)

Figure 3. The tablet edition magazine environmental impact in the selected categories for the reference scenario (per reader of a copy): (a) Emerging version (current 2010) (b) Mature version (possible future). (Diagram from Paper I)

3.2. Print edition

For the print edition, as shown in Figure 4, pulp and paper production is the main contributor to the potential environmental impacts—except metal depletion impact, for which printing is the main reason. The recycling of the waste magazine paper may considerably offset environmental impacts if newsprint production from virgin fiber can be avoided.

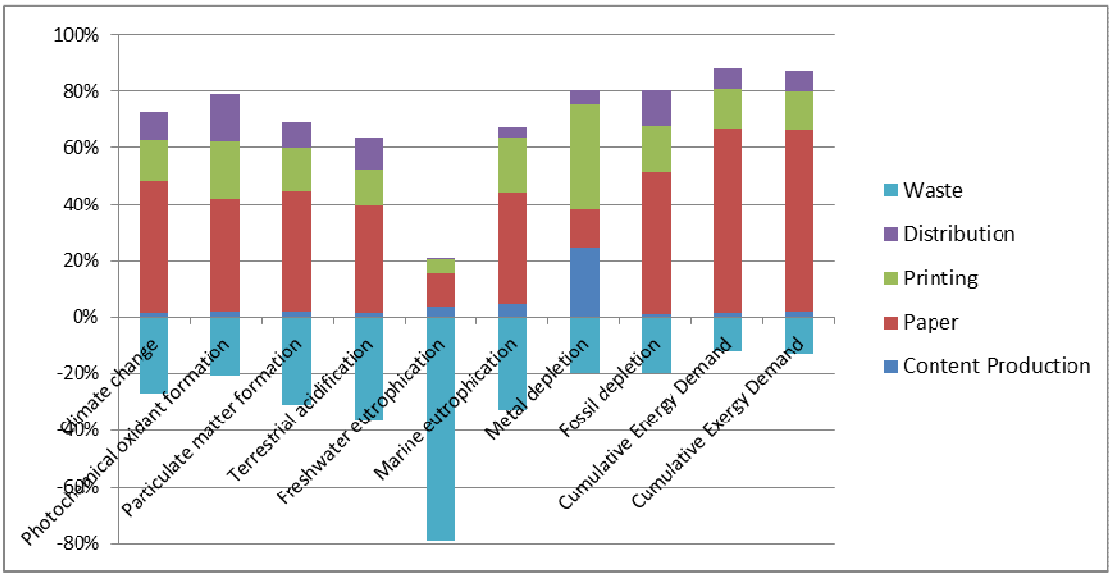


Figure 4. Environmental impact (per reader of a copy) of the print edition of the magazine in the selected categories for the reference scenario. (Diagram from Paper II)

3.3. Comparison of tablet and print editions

When comparing the tablet and print edition of the magazine studied, the importance of the functional unit is clear (see Figure 5 for impact per reader, and Figure 6 for impact per copy). Also, whether the tablet edition is in the emerging or the mature version makes a considerable difference.

Three different functional units were used within the overall assessment made. The emerging tablet edition here gives rise to more environmental impacts *per reader* than the print and mature tablet edition. This is even more so when considering the environmental impacts *per reading hour*. This is a consequence of the emerging edition having fewer readers and also lower reading time per reader.

On the other hand, if the environmental impacts are related to *a copy* of the magazine the print edition gives the highest environmental impacts in most of the impact categories.

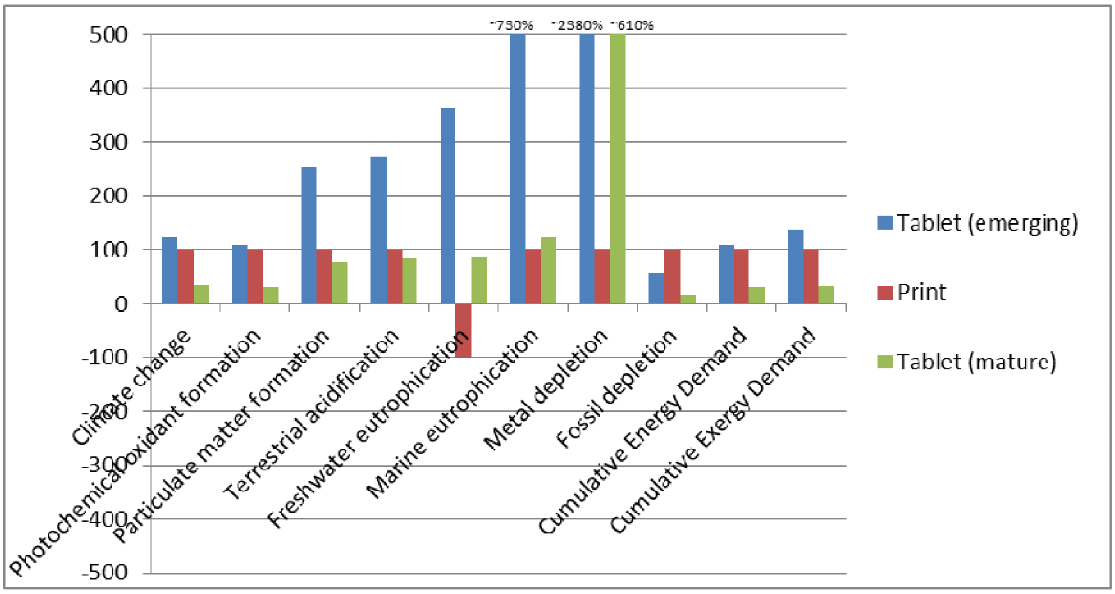


Figure 5. Comparison between print and tablet editions of the magazine in the reference scenario (impact per reader). Print reference scenario = 100. (Diagram from Paper II)

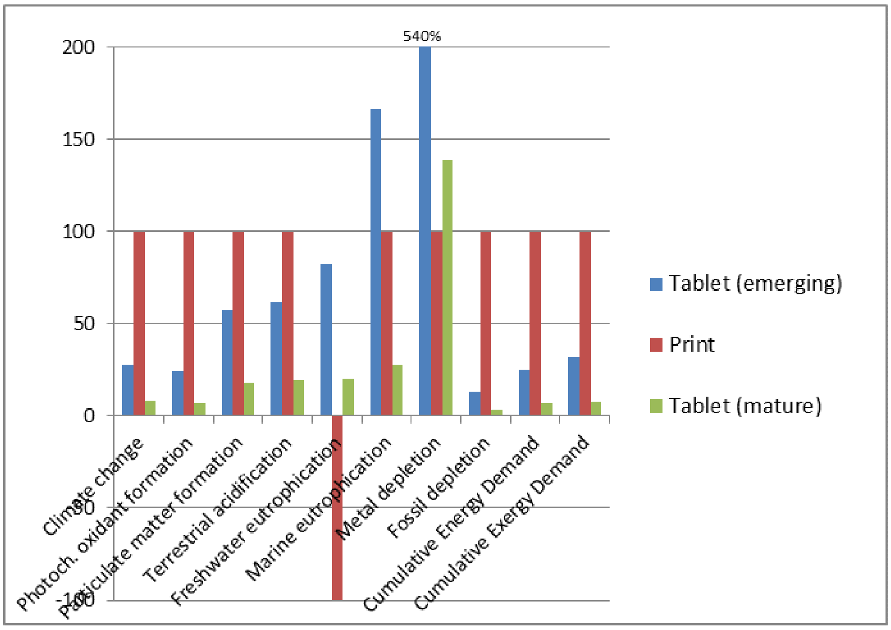


Figure 6. Comparison between print and tablet editions of the magazine when the impact is assessed per copy as the functional unit. Print = 100. (Diagram from Paper II)

4. Discussion

4.1. Relating the thesis to previous studies

The results of Paper I and II can be seen in light of the three-level effects of ICT on environment, presented in Table 1 (Berkhout and Hertin 2004). Table 3 shows positive and negative impacts of the tablet edition of the magazine studied in the thesis, putting the results of Paper I and II in the context the framework discussed in Berkhout and Hertin (2004).

As for direct effects, following this framework, only negative impacts of production, use, and disposal of ICTs associated with the tablet edition of the magazine have been mentioned in Table 3. However, one may include the positive direct effects such as raising social awareness on environmental sustainability via reading magazines. This was not covered in the present thesis.

As shown in Table 3, there are some impacts of ICT on the environment that are not addressed in Papers I and II. Such impacts can be further studied in future research.

Table 3. Impacts of the tablet edition of the magazine studied in Paper I and II

	Positive impacts	Negative impacts
Direct effects	-	Environmental impacts of life cycle activities of the tablet device and the communications infrastructure were assessed.
Indirect effects	Partial substitution (de-materialization) and/or complete substitution (virtualization) of print edition of magazine and thus avoiding or reducing environmental impacts associated with the print edition	*
Structural and behavioral effects	*	*

* Not addressed in the thesis

The use of the tablet, including a relevant share of manufacturing and disposal, was not the major reason for environmental impacts for the emerging version, and in the mature version only for some impact categories. The electronic devices used have in previous studies been related to a considerable share of the environmental impacts (Moberg et al. 2010; Kronqvist et al. 2010). The assumption made on overall use of the tablet device was tested, since it affects the share of environmental impacts related to manufacturing that is allocated to the reading of this specific magazine. The results presented in paper I illustrate the influence of the user practices on the assessment. With inefficient use of devices, the environmental impacts related to manufacturing are high per benefit provided, and are often a major part of the overall impacts of the media product system. This is in line with previous studies in the field. What was new in this study was, as described above, that the content production was clearly dominating for many impact categories even at low overall use of the device if few readers were accessing the content (emerging state).

In an LCA study of an E-ink tablet e-paper newspaper—where the functional unit of the study was 'the consumption of a newspaper during one year by one unique reader'—Moberg et al. (2010) showed that for many impact categories, the production of the tablet device made up the largest part of the tablet newspaper life cycle (e.g. around 85% of total CO_2 eq. emissions in the Swedish scenario). This is different than in our study where content production (in emerging version) or electronic distribution (in mature version) plays the major role. Moberg et al. (2010) studied a newspaper rather than a magazine, and key assumptions included the reading time of 30 minutes per day and that the device was used 50% of the overall use time for this purpose. These assumptions of course lead to a higher share of the manufacturing environmental impacts than our study where 0.20 and 1.3%, for emerging and mature versions respectively, of the overall use time of the tablet is for the magazine studied. It should be noted that in the study by Moberg et al. (2010), data on content production was limited only to electricity and heat, compared to the more detailed study in our analysis. Also the electronic distribution data in their study were limited and uncertain. The assumption in our study on total use of the tablet is uncertain and proves important for the overall outcome of the study.

Kronqvist et al (2010) present results for an electronic magazine read from a laptop computer. Their results show that the manufacturing of the laptop is the major reason for the electronic magazine environmental impact. The reading time per issue is in their study 40 minutes, thus more similar to the mature version here. For the content production they model only travel and energy use at the office, and the same environmental impact for content production is assumed for the reading of a printed and electronic magazine. Also the electronic distribution data are limited and not allocated based on data size. Thus, the differences in results are partly due to the use of another type of electronic device, but also to several other factors.

4.2. Allocation

4.2.1. Allocation of content production

A main activity in the life cycle of *Sköna Hem* is content production. When modeling the print and tablet editions of the magazine, the content production environmental impact was allocated to both editions. It was not easy to decide how this allocation should be made. There was 0.5 full-time employee equivalents (FTEs) specifically working with the tablet version, and thus naturally accounted for in that product system. For the rest of the content production environmental impact an allocation was made based on the number of copies sold—2 212 electronic copies per year and 1 307 600 print copies per year gives 0.2% of the rest of the content production environmental impact to the tablet emerging version. In total, 1.7% of the content production was allocated to the tablet emerging version. For the mature version, this share was 50%, i.e. 653 500 electronic copies per year and 653 500 print copies per year (see Table 4).

The production of content is here accounted for as total electricity use, heating, cooling, business trips, transportation by delivery firms, electronic office equipment, and office paper used. These processes are described in further detail in Paper I. For all these processes information was gathered from *Sköna Hem* for the year 2010. The data provided does not cover production of advertisement, which is excluded from the assessment. Even though advertisement is a rather large part of the magazine content it is produced for many different users, not only *Sköna Hem*, and we assume that the environmental impacts related to the advertisement part of *Sköna Hem* content is small compared to the other content production. Further studies are however needed to test this assumption.

At the company *Sköna Hem* the employees are producing content for the magazine, but also giving courses in interior design. In this study we want to cover the environmental impact of the content production for the magazine only, and thus, some of the environmental impact related to *Sköna Hem* overall needs to be excluded (i.e. we need to make an allocation between different functions, magazines and courses).

In total, 14.8 fulltime employee equivalents (FTEs) work at the office, 13.8 FTEs are dedicated to the magazine part (1 FTE out of 14.8 FTE was dedicated only for courses, not the magazine part) and thus 93% [13.8/14.8] of the environmental impact are allocated to the magazines and included in the assessment.

In addition to the employees at the office, 12 FTE freelancers are contributing to editorial work for the magazines. We have not been able to gather information specifically for the freelancers, but have assumed that the environmental impacts was similar (per FTE) to those of the employees, as described below. However, for 0.5 FTE freelancers' specific data was gathered, which is for indoor photo sessions. Thus an additional environmental impact was added for freelancers, accounted for as a share of the overall information for *Sköna Hem* 78% [(12-0.5)/14.8], where 14.8 is the overall environmental impact reported for *Sköna Hem*. These extra 78% were added to the relevant content production processes. As an exception, the environmental impacts of transportation by the delivery firm are all allocated to the editorial activities totally (not allocated to courses), and no additional transportation are added for the freelancers. In the same way, all business trips are assumed to be for editorial purposes (not allocated to courses) and the data given by *Sköna Hem* include freelancers' business trips. All figures given below are for the *Sköna Hem* office in total, the allocations are made in the modeling.

Table 4 presents the allocation formula used in the allocation of content production between the print and tablet editions. Table 5 shows the impact of content production in all versions.

Table 4. Formula used for the allocation content production in print and tablet editions

FORMULA USED FOR TABLET EDITION

Impact (per reader) of CP, electronic share =

[Impact (per year) of CP, common] * (ShareOfCP4Electronic / (N_e_copies))
+
[Impact (per year) of CP, only for tablet edition] * (1 / (N_e_copies))

where,

ShareOfCP4Electronic = N_e_copies / (N_e_copies+N_p_copies)

N_e_copies = 2212 for emerging tablet
= 653500 for mature tablet

N_p_copies = 1307000 for emerging tablet
= 653500 for mature tablet

FORMULA USED FOR PRINT EDITION (Impact=Impact per reader)

Impact (per reader) of CP, print share =

[Impact (per year) of CP, common] * ShareOfCP4printed / (14*93400*4.4)

where,

ShareOfCP4printed = 1-ShareOfCP4Electronic
14: number of issues per year
93400: number of copies per issue
4.4: number of readers per print copy

Note: Impact (below) = impact per year
[Impact of CP, common] =

[Impact of CP.electronic devices] * ((13.3/14.8)+(11.5/14.8)) +
[Impact of CP.business trips] * 1 +
[Impact of CP.deliveries (bud)] * 1 +
[Impact of CP.office paper incl. disposal] * ((13.3/14.8)+(11.5/14.8)) +
[Impact of CP.studio photo sessions] * 1 +
[Impact of CP.heating] * ((13.3/14.8)+(11.5/14.8)) +
[Impact of CP.electricity] * ((13.3/14.8)+(11.5/14.8)) +
[Impact of CP.cooling] * ((13.3/14.8)+(11.5/14.8))

Note: Impact (below) = impact per year
[Impact of CP, only for tablet edition] =

[Impact of CP.electronic devices] * (0.5/14.8) +
[Impact of CP.office paper incl. disposal] * (0.5/14.8) +
[Impact of CP.heating] * (0.5/14.8) +
[Impact of CP.electricity] * (0.5/14.8) +
[Impact of CP.cooling] * (0.5/14.8)

where,

14.8: full time employee equivalents (13.8 editorial + 1 course teacher)
11.5: freelancers (subcontractors)
0.5: full-time employee equivalents specifically working with the tablet edition

Table 5. climate change impact of content production in various magazine versions

	kg CO_2 eq / copy	kg CO_2 eq / reader
Tablet, emerging	0.159	0.159
Print, when emerging tablet assumed	0.0193	0.00438
Tablet, mature	0.0198	0.0198

4.2.2. Allocation based on size of data

Allocation of electronic distribution impact in Paper I was based on the size of the data (MB) transferred over the network—except the electricity consumption in the operation of home networking (modem/router), the allocation of which was based on reading time of the tablet edition.

The allocation based on data size was consistent with previous studies on electronic distribution of media (Koomey et al. 2004; Weber et al. 2010; Moberg et al. 2011). In their study of network energy use associated with of PDAs, in order to solve the allocation situation of multi-functionality of the communications network, Koomey et al. (2004) presented an allocation approach (claimed to be "the first systematic attempt" in the field) to allocate network electricity use in proportion to data flows. According to their approach, by estimating the annual data flow for a certain task or service (in their case, for end-use devices like PDAs in the USA), one can assign some fraction of the total environmental burden of the network to that task or service, based on the ratio of the task's data flow to the total data flow for each major network component (i.e., the Internet, the standard telephone system, and the cellular system). Koomey et al. (2004) made an allocation (partitioning) in proportion to a physical property of functions—as explained in (Ekvall & Finnveden 2001). This physical property in the case of electronic distribution is the data flow measured in bits or Bytes.

4.2.3. Allocation based on use time

The impact of production, distribution, and disposal of tablet was allocated to the reading of the tablet edition, based on the use time. This was consistent with the allocation approach in previous studies of electronic media (Moberg et al. 2010; Moberg et al. 2011).

The overall use time of the tablet studied was assumed to be 14 hours/week (in the reference scenario) during a 3-year lifetime. To assess the impact per reader and per copy, only 9 minutes in the emerging version (41 minutes in the mature version) of this overall use time were allocated to the reading of a copy of the tablet edition.

This means that environmental impacts related to the tablet device will be split on the total use of the device during its lifetime; little overall active use means relatively higher impact per hour of use and high overall active use relatively lower impact per hour of use. The average charging time per reading time is necessary to consider as the overall electricity use of the tablet needs to be split on the different uses.

Sensitivity analyses on the overall use time of the tablet device (for both emerging and mature versions) showed that assuming the low one hour per week use of the tablet during the three years of use the overall results were different. With low use of the device, the potential environmental impact of the emerging tablet edition was increased slightly. However, for the mature tablet edition, the impact increase was more notable. In the mature version the reading time of the magazine studied is assumed to be higher (41 min/issue), and as the tablet manufacturing impact is related to the use time the change in the assumption of overall use time of the device has a higher influence on this version.

4.3. Reflection on methodology

4.3.1. Data collection prioritization

In the inventory phase of the LCA study, I gathered data on inputs and outputs of each life-cycle activity: inputs of material and energy, and outputs of emissions (to water, air, and ground), as well as waste.

In an ideal scenario, an analyst could expect to collect all inventory data associated with life-cycle activities of the product system under study. However, in the real world, given the uneven maturity of environmental information systems and also accounting approaches used in industry, it is difficult, sometimes impossible, for the analyst to gather all data. Further, since every LCA study is a project with specific goals and certain resource constraints (e.g., time and budget), the analyst must consider the data collection process within these constraints.

During the present study, the necessity, importance, or cost of collecting the needed data were often substantial. It was reasonable, of course, not to gather data which were outside the study's scope. However, there were moments when the sought-after data supposed were inside the defined scope, but due to considerations associated with study goals or project constraints, I had to prioritize the data collection tasks. At these moments, usually I relied on the expert advice of my supervisor or on previous assessments in deciding whether to choose or not to choose to gather a certain piece of data.

Now the question is: What are the scientific foundations of expert judgments in such data collection prioritization? How can I prioritize which data to collect in order to minimize the cost of the assessment and maximize its reliability?

As Alan Chalmers (2003) notes: "At least since the writings of Karl Popper and Thomas Kuhn made their impact on the philosophy of science it has become commonplace to regard observation and experiment in science to be theory-dependent in some significant respect."

Theory dependence in natural science means that our observations "start out from our conceptions about what types of empirical observations are most suitable for finding out the regularities in nature. These conceptions, in their turn, are not 'purely theoretical', but are based on previous empirical observations" (Hansson 2007, 33).

Interpreting this definition in the context of my research method (LCA), I maintain that theory dependence in LCA means that my data collection process (in the inventory phase) starts from my conceptions about what types of empirical evidence are most suitable for analyzing environmental impact of the product system under study (to achieve the study goals).

For instance, consider the following example of data collection on the cover paper of the magazine in Paper II:

> Two types of paper are used in the print magazine, one for inset and another for cover. The inset consists of the paper NovaPress 75 g/m^2 (gloss) and the cover is Tom&Otto 200 g/m^2 (gloss), both produced in Finland.
>
> Data from the environmental product declarations (EPDs) were used (Stora Enso 2011). The EPDs include figures on the following environmental parameters: emissions to water (COD, AOX, N and P) and air (CO_2, SO_2, and NO_x), electricity consumption, and solid waste landfilled. The figures cover the production of pulp and paper.
>
> The pulp used for the cover paper is produced in Brazil. The forestry data were not available, but it is transported by ship to Finland (Partanen 2011). The transportation was modeled using the Ecoinvent dataset "Transport, transoceanic freight ship/OCE" (Spielmann et al. 2007).
>
> Data on the forestry used to provide pulp for cover paper are lacking. Because of confidentiality, the production mill did not provide more details. However, since the cover paper represents only 5.5% of the magazine, the details of its forestry were overlooked.

For the cover paper, inventory data were collected on the production of pulp and paper and on distribution; however, the data on forestry were missing (the data were not provided by the company, which cited confidentiality). As reasoned above, since the share of the cover paper is only 5.5% of the total paper used in the magazine (and the forestry data for the inset paper, which has the 94.5% share, had been collected), the details of the forestry for the cover paper were obscured.

This can be seen as an example of a theory-dependent observation which assumes a similarity between the level of impact of forestry associated with cover paper and that of forestry associated with inset paper.

In order to quantify the extent to which a scientific inquiry is theory-dependent, one can employ, for example, Bayesian networks[2] (Neapolitan 2004) for assessing

[2] Bayesian networks are often employed for probabilistic inference. Bayesian networks are composed of three components: nodes, representing system variables; values (probabilities)

environmental impacts. These networks can be combined with a diagnosis algorithm for prioritizing which data to collect in order to minimize the cost of the assessment, without harming its scientific objectivity. This is a topic for future research. Relating this question to uncertainty analysis approaches in LCA, one could benefit from Bayesian-statistics-based approaches developed in the field of LCA (Lo et al. 2005).

4.4. Limitations and need for further research

The study included some significant data gaps and data uncertainties. Some of these are described here.

There are major data gaps concerning the toxicological impact categories for the pulp and paper manufacturing if specific data is to be used; also relevant information on printing supply material is limited. Thus, these impact categories were not assessed for the print version. Using generic data for the electronic components of the tablet provides more comprehensive data sets, but these are not specific to the actual product type studied and thus uncertain. Also, these generic data are quite old. Improved data are needed for both product systems studied for further studies and more comprehensive assessments.

Inherent uncertainties are related to the user practices, as these are varying between different users. In the reference scenarios in Paper I and II the aim was to describe an average user. The information and assumptions used in the study were tested in sensitivity analyses presented in Paper I and II. However, future work that assesses the environmental impact of electronic media would benefit from collecting data on how consumers use various print and electronic media differently, and from modeling the complex system of user practices to get less uncertain results.

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associated with nodes; and arcs between the nodes, representing causal relationships between these nodes.

5. Conclusions

Based on the assessment performed in the thesis, it is clear that for the print magazine studied, pulp and paper production is the main reason for most of the potential environmental impacts assessed. Also, the recycling of the waste magazine paper may considerably offset environmental impacts if newsprint production from virgin fiber can be avoided.

For the tablet edition, the content production totally dominates the potential environmental impacts when readers are few. This may be the case in an emerging state of the magazine, but with the possibility of distributing more media products to smaller groups of people this may become more common for "mature" products as well. With more readers the impact of the tablet edition is to a larger extent due to manufacturing of the tablet device and electronic distribution but also still content production may be major reasons depending on the type of environmental impacts studied .

The overall number of readers for the tablet version and the number of readers per copy for the print edition are crucial to the resulting potential environmental impacts per reader. The electricity mix used in the processes of the products' systems may also significantly affect the resulting environmental impacts as well as the total use time of the tablet during its service life.

With a higher number of readers per issue for the tablet edition, the impacts of content production will be lower per reader. The environmental impacts of manufacturing and disposal of the device related to the magazine can be reduced if the reader uses the tablet efficiently, i.e. use it for many purposes and during a long life time it will be lower per reading time.

Media products can be assessed using different functional units. Depending on which functional unit is used the preference is different for print or electronic editions of the magazine. When considering the environmental impact related to a reader of the magazine, for most impact categories the emerging tablet edition has the highest impact and the mature tablet edition the lowest, print edition in between. If the assessment is made in relation to a single copy the print edition is in most impact categories giving rise to highest impact. Considering the functional unit to be a reading hour the emerging tablet version is increasingly dominating regarding environmental impacts, 5 times higher than the print edition or more. It can be concluded that the definition of the function provided by the media product studied is of high importance and will affect the overall results of an assessment.

The major limitations and uncertainties in the assessment were presented in Paper I and II. However, the overall results regarding identification of key factors affecting the comparative results and the importance of formulation of the functional unit are believed to hold true also with these uncertainties. To be able to compare also toxicological impacts, and overall use updated, comprehensive and specific data may well open up for new interesting results.

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