

Climate Change Impact of Electronic Media Solutions: Case Study of the Tablet Edition of a Magazine

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ABSTRACT

Shifts from print media to electronic media may be regarded as a possibility for promoting sustainability. However, the benefits of electronic media are not unquestioned. Previous studies on the environmental impacts of print and electronic media have shown that there is no easy answer. Contributing to this field of research, the present study sought to assess the climate change impact of the tablet edition of a magazine using a life cycle perspective. Results showed that with few readers the emerging tablet version had a higher potential climate change impact per reader than the mature tablet version, although the latter had a substantially longer reading time per copy. The contribution of content production, electronic distribution, reading on tablet and waste treatment of tablet to the impact was analysed. The sensitivity analysis of electricity mix indicated that this was an important factor that clearly influenced the overall results.

Keywords

Climate change, carbon footprint, information and communications technology (ICT), electronic media, industrial ecology, life cycle assessment (LCA), technology and environment, magazines

1. INTRODUCTION

In our path toward a more sustainable society, it is critical to have a better understanding of the environmental burdens of both conventional products and their new alternatives. Scientific measurements of these burdens using credible tools (such as life cycle assessment, LCA) can support informed decisions on production and consumption of products.

The media sector is experiencing considerable changes. Enabled by information and communication technology (ICT), new ways of distributing content are being developed and widely used. Shifts from print media to electronic media may be regarded as a possibility for promoting sustainability. For example, by dematerialising media products such as newspapers, books and magazines in their electronic version, forest resources and energy are not needed for paper production and environmental impacts associated with the distribution of print media can be avoided.

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However, the benefits of electronic media and ICT-based solutions are not unquestioned. Environmental drawbacks of ICT have been addressed in the literature (e.g. [4], [25]). Previous studies on the environmental impacts of print and electronic media have shown that there is no easy answer regarding the type of product that is preferable from an environmental perspective (e.g. [21], [17], [22], [9], [13]). These studies include media products such as daily newspapers, literary books, scholarly books and magazines and their electronic versions read on the computer, except for a study on books and a study on newspapers [21, 22], in which an e-ink tablet device is studied.

Contributing to this field of research, the present study sought to assess the climate change impact of the tablet edition of a magazine using a life cycle perspective. The study examined the impacts of the tablet edition in its current *emerging* state, which 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. 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.

2. METHOD AND DATA

2.1 Life cycle assessment

Life cycle assessment was used for the assessment, here focusing on the potential climate impact. The methodology provides standard guidance on the compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout the life cycle [2]. The life cycle includes extraction of raw material, production, use and disposal of a product (i.e. from cradle to grave). The standard methodological guidelines as specified in ISO 14044 [16] were followed in this study.

In this LCA we used the modelling and analysis software SimaPro, version 7.2.2. Data were primarily chosen from actors in the supply chain of the product studied. When this was not possible, data were taken from the Ecoinvent 2.2 database [14]. The impact assessment method ReCiPe was used [12].

2.2 The system

The system boundary, which represents the life cycle processes considered in the present study, included the content production

(district heating and cooling, electricity, office paper, production of electronic office equipment, transportation of electronic office equipment, business trips, transportation by delivery firms, and studio photo sessions), electronic distribution of the magazine (modem, router, access network, internet infrastructure, data centre, and operator activities), as well as production, distribution and disposal of the tablet and electricity use for reading the magazine on the tablet. Moreover, based on the assumptions and estimations made by a recycling company, waste treatment of the studied tablet was covered, assuming that 80% of the discarded tablet was processed in a recycling system and the remaining 20% went to incineration.

The basic functional unit in this study was defined as: One reader's use of one copy of the tablet edition of a magazine, and the year studied was 2010. The magazine, called *Sköna Hem*, focuses on interior design and has 14 issues per year.

Some important parameters defining the system studied are presented in Table 1. The life time of tablet device was assumed to be 3 years, which is consistent with other studies [1]. The large size of the electronic magazine (163 MB) is mainly due to its high-quality photos associated with the magazine's focus on interior design.

Table 1. Description of the system studied

Parameter	Value	Unit
Size of one magazine stored on server	163	MB / copy
Number of downloads per issue (emerging state)	158	downloads / issue
Number of downloads per issue (mature state)	46 679	downloads / issue
Reading time (emerging state)	9	min / copy
Reading time (mature state)	41	min / copy
Life time of device	3	Years
Share of overall content production allocated to the tablet version (emerging state)	1.7	%
Share of overall content production allocated to the tablet version (mature state)	50	%

2.3 Life cycle inventory data

Life cycle inventory data are briefly presented below. For processes taking place in Sweden we used Swedish electricity mix [11], sources of which are shown in Table 2. This Swedish mix gives 102 g CO₂eq/kWh. Data on electricity production and distribution were taken from the Ecoinvent database, "Electricity, low voltage, at grid/SE" [6].

2.3.1 Content production

Inventoried processes for content production included total electricity use in the office, district heating and cooling, production and transportation of electronic office equipment, business trips, office paper, transportation by delivery firms, and studio photo sessions. Some office activities are shared between employees who produce the content and those who organise courses in interior design. Environmental impacts were allocated here based on full-time employee equivalents (FTEs). In total, 14.8 fulltime FTEs work at the office: 13.8 FTEs are dedicated to

magazine content production and 1 FTE works only on the courses (the impact of the latter was excluded from our analysis).

The electricity use at the *Sköna Hem* office (83 kWh/m² in 2010 [23]) includes all electricity consumed at the office (including light, electronic devices and office equipment).

The carbon footprint of district heating used in the office (59 kWh/m² in 2010 [23]) was 82 g CO₂eq/kWh [10]. For district cooling (50 kWh/m² [23]), according to the energy company [29] 'green electricity' was used, which we modelled using a dataset for Swedish hydropower electricity at the grid [8]. The building where the office is located contains cellar storage, restaurant, shops and offices. It was not possible to get specific information on heat consumption for office space, so the average figure used is an estimation.

Data on manufacturing of electronic office equipment (as well as raw material extraction and transportation) were taken from the Ecoinvent database [18]. To model LCD screens of various sizes (20, 21, 27, and 26 inches), data for a 17" LCD flat screen were used. Since there is no suggested or straight-forward way to extrapolate the environmental inputs and outputs to larger screen sizes, the data were used unadjusted. This may have meant a slight underestimation of impact. Copy machines were modelled based on printer laser jet data. Emissions from the production and transportation of mobile phones were taken into account [3]. The production of the scanner was not modelled due to lack of data.

Table 2. Sources of electricity in Swedish and UCTE mix [11]

Electricity source in Swedish mix	Share (%)	Electricity source in UCTE mix	Share (%)
Nuclear, domestic	46	Fossil	51
Hydropower, domestic	36	Nuclear	32
Finnish mix, import	4.3	Hydropower	11
Natural wood chips, domestic	4	Pumping storage ("pumpspeicherung")	1.3
Danish mix, import	1.5	Renewables	3.1
Norwegian mix, import	1.4	Waste	1.4
Polish mix, import	1.4		
Oil, domestic	1.2		

The transportation of electronic office equipment was assumed to be by boat from Shanghai to Europe (Rotterdam) and further to the users in Stockholm by truck (>16 tons). Data on truck and freight ship transportation were taken from the Ecoinvent database [28].

For business trips by the employees, the impact of three return flights from Stockholm to Paris and seven from Stockholm to Milan [5] was modelled using data for transport by aircraft in Europe [28]. The impact of taxi trips (total distance of taxi trips estimated at 1186 km, based on expenditure figures) was modelled using a dataset for transport by passenger car in Europe [28]. Taxi expenditure data also included trips by freelance staff. Public transportation was not included in the inventory data.

Sköna Hem has on average 50 studio photo sessions per year. The environmental impact of the photo sessions is hard to assess, since there are no readily available data on environmental parameters for this. Included in the modeling of the photo sessions environmental impact is transport of the photographer, electronic equipment and energy use in the studio. For transportation it is assumed that the photographer uses a car, and an average distance within Stockholm area is roughly assumed as 3 km.

Allocation of content production. The environmental impact of content production was split between the print and tablet editions of the magazine. The 0.5 FTE specifically working with the tablet edition was naturally accounted for in that product system. For the rest of the impact of content production, 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), giving 0.2% of the remaining impact of content production 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.

2.3.2 Electronic distribution

The tablet magazine was assumed to be downloaded to a tablet device in the format of a 163 MB app file through a WiFi wireless LAN. The distribution network (Table 3) was mainly modelled based on the study by Malmodin and Lundén [20] with updated results gathered in personal communication with Malmodin [19]. In addition, a dataset from Ecoinvent was used, as described in Table 3.

Table 3. Network components and their electricity use and manufacturing greenhouse gas emissions in 2010 for an average user

Network components	Electricity, at operation	Manufacturing Emissions
CPE (customer premises equipment), average of modem and router setups in Sweden, which means 100% of users have modems and 50% of users have routers.	Modem (9W): 0.22 kWh/GB Router (9W): 0.11 kWh/GB	3.6 g CO ₂ e / GB [Ecoinvent dataset: "Network access devices, internet, at user/CH/I," assuming 360 GB per subscriber line per year]
Access network: DSLAM, cables	DSLAM: 0.083 kWh/GB	
Data transport/transmission and IP edge/metro/ core network ~ Internet	0.1 kWh/GB	14 g CO ₂ e / GB
Data center	0.4 kWh/GB	25 g CO ₂ e / GB
Cable infrastructure	-	14 g CO ₂ e / GB
Operator activities: cars, offices, office equipment, paper, operational maintenance	0.009 kWh/GB	11 g CO ₂ e / GB (not manufacturing, but heating and travel related to operator activities)

2.3.3 Reading magazine

2.3.3.1 Production & distribution of tablet

To inventory production of a tablet device, an iPad2 was obtained and disassembled into pieces that could be identified by the technical specification for the tablet. The weight and size of these disassembled parts were measured [7]. The manufacturing of components was modelled using the Ecoinvent database [14]. Contacting Apple for detailed data on the environmental impacts of manufacturing proved unfruitful. Thus to model the assembly electricity consumed in tablet production, we applied as an estimate the amount of electricity used for assembly in laptop production, as modelled in the Ecoinvent dataset "Laptop computer, at plant/GLO" (1.67 kWh per pcs). Assuming assembly in China, the Ecoinvent dataset "Electricity, medium voltage, at grid/CN" was used (1180 g CO₂eq/kWh).

There were some data missing in modelling the components of the tablet, including the capacitive touch film and flex film (multi-touch screen type). Apple's data on GHG emissions from the manufacturing of iPad2 indicate 63 kg CO₂e/device (including packaging), while the modelled tablet in this study gave 36.2 kg CO₂e.

Transportation of the tablet was assumed to be by boat from Shanghai to Europe and further to the users in Stockholm by truck. The impact of tablet production and distribution was allocated to reading of the tablet edition, based on the use time. The overall reading time of the tablet was assumed to be 14 hours/week during a 3-year lifetime.

2.3.3.2 Electricity use of reading magazine on tablet

From the technical specifications of the iPad2 [1, 15], we calculated the energy use for reading the magazine, based on the electricity consumed for charging the battery and the maximum battery life in Wi-Fi mode. The energy use per charging session is 41.85 Wh, and the tablet use time supported by one charging session in Wi-Fi mode is 10 h.

2.3.4 Waste treatment of tablet

Data on possible disposal of the tablet were gathered from the electronics recycling company Stena Technoworld [27]. They examined the tablet device disassembled earlier in this project, and provided an indication of how a tablet device could be disposed of.

For all tablets, it was assumed that 20% of the discarded tablet is not processed in a recycling system, but goes directly to a municipal waste incineration plant, a similar assumption to that in a previous study on mobile phones [26]. Both recycling and incineration were credited for producing secondary raw materials and heat and electricity by expanding the system and assuming that these additional products provided by the studied system replaced the same produced from primary raw materials.

2.3.5 Sensitivity analyses

2.3.5.1 UCTE electricity mix

A sensitivity analysis was conducted for the electricity mix by replacing the Swedish electricity mix used in the study by an average European electricity mix, i.e. Union for the Co-ordination of Transmission of Electricity (UCTE) mix [11], sources of which are shown in Table 2. This was done in order to investigate whether using Swedish electricity mix with the majority originating from hydro and nuclear power had a significant influence on the results. If this were the case, the same kind of magazine in another European country would have a considerably different potential impact. The UCTE mix gives 594 g CO₂eq/kWh [6].

2.3.5.2 Overall use time of tablet

The assumption on overall use of the tablet device is highly uncertain and will vary greatly between different readers. Thus, this assumption was tested in sensitivity analysis. The results of the reference scenario indicated that manufacturing of the tablet device, which is the part where the resulting impact is affected by the overall use time assumed, was a minor reason for the overall potential impact. Therefore only the lower use was tested in the sensitivity analysis.

2.3.6 High number of electronic copies

As the reference scenario showed that the content production may be of high importance for the tablet version when few copies are

produced, the number of copies was raised considerably in a sensitivity analysis for the emerging version.

3. RESULTS

Figure 1 presents the potential climate change impact associated with different activities in the life cycle of emerging and mature versions of the tablet edition of *Sköna Hem*.

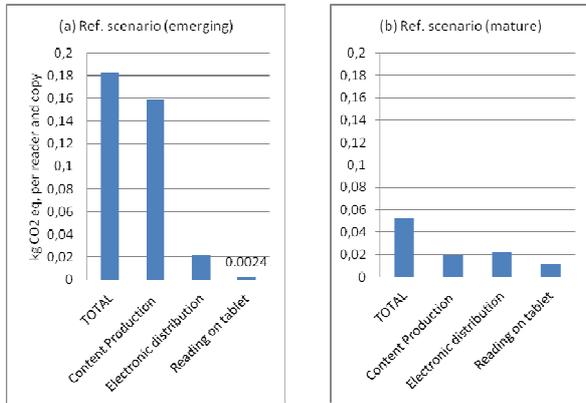


Figure 1. Climate change impact of (a) the emerging and (b) the mature version of the tablet magazine in the reference scenarios (per reader of a copy)

3.1 Emerging version

As shown in Figure 1a, the total impact for the emerging version was approximately 0.18 kg CO₂e. per reader and copy.

The emissions associated with content production (0.16 kg CO₂e. per reader and copy) dominated the life cycle activities. This was due to the impact of content production specific to the tablet edition being allocated to few copies of the emerging version. The major contributors to the climate change impact of content production are the production of electronic devices (46% contribution, mainly desktop computers and LCD screens) and electricity consumption in the office (27% contribution).

3.2 Mature version

Figure 1b shows the potential climate change impact of a possible future, more mature, tablet version of *Sköna Hem*. Its impact per reader was less than half that of the current emerging tablet version and content production was of less importance. In this mature scenario, the impact of electronic distribution was higher than that of content production. However, content production still had a slightly higher impact than tablet use (which includes a relevant share of manufacturing and disposal). Thus in this mature tablet version, electronic distribution (42%) and content production (37%) were the major contributors to the climate impact.

Moreover, the impact of electronic distribution in both the emerging and mature versions was mainly due to electricity use in operation (around 30%) and manufacturing of data (around 20%).

3.3 Sensitivity analyses

3.3.1 UCTE electricity mix

As shown in Figure 2, replacing the Swedish electricity mix with the average European (UCTE) mix increased the potential climate change impact for both emerging and mature versions by more than 100%.

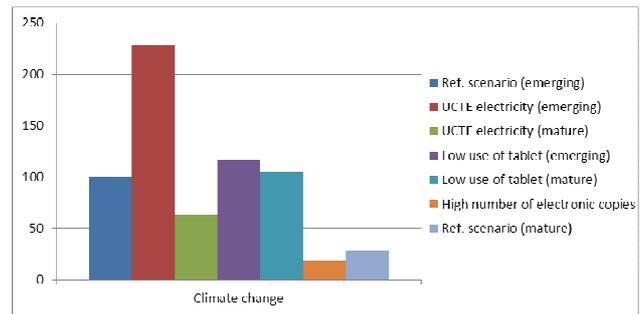


Figure 2. Sensitivity analyses for the tablet magazine concerning the electricity mix, total use time of tablet and number of electronic copies. The effect of the changed assumptions is illustrated in relation to the potential climate impacts of the reference scenarios (emerging ref. = 100).

3.3.2 Overall use time of tablet

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 gave different overall results for the mature version, but not for the emerging version (see Figure 2). For the mature tablet magazine, the impact increase was around 300%. In the mature version, the reading time of the magazine was assumed to be higher (41 min/issue), and as the tablet manufacturing impact is related to the use time, the change in assumed overall use time of the device had a higher influence on this version. However, the assumption in our study on total use of the tablet was uncertain and proved to be important for the overall outcome of the study.

3.3.3 High number of electronic copies

For the emerging version, the sensitivity analysis on the number of electronic copies downloaded showed that a considerable increase in the number of electronic copies brought a considerable decrease in the environmental impact per reader (Figure 2). This was because the overall environmental impact of content production was allocated over a larger number of copies.

4. DISCUSSION

4.1 Main results of the study

For the emerging version, the results showed that the climate change impact of content production, which is usually a smaller share for print media according to previous studies [21, 22], played a major role, making an approximately 85% contribution. This was due to the environmental impact related to content production activities specific for the tablet version being split between few copies.

For the mature version, the overall climate change impact (per reader and copy) was less than half that of the emerging version. The electronic distribution and content production were the major contributors to the climate impact.

Use of the device was not the main contributor to potential impact in this assessment, unlike in previous studies where other electronic devices have been used for the electronic media (e.g. [21]). Furthermore the assumption on overall use of the tablet device was uncertain and will differ between users. When assuming a low use of one hour per week use for three years, the climate change impact was not much changed for the emerging version of the tablet magazine. However, for the mature version,

the increase was considerable (360%). This lower overall use of the tablet use meant that it became the major contributor to the climate impact (nearly 80%). This emphasises the need to use electronic devices efficiently and also to avoid upgrading to new versions too often.

The sensitivity analysis of electricity mix indicated that this was an important factor that clearly influenced the overall results. Changing from Swedish to a European average electricity mix (UCTE) would generally increase the potential environmental burdens of tablet magazine. For example, the potential climate change impact of the mature version increased by more than 550%.

4.2 Comparison with previous studies

An LCA study of an E-ink tablet e-paper newspaper in which the functional unit of the study was 'the consumption of a newspaper during one year by one unique reader' [22] found that for the climate change impact category, production of the tablet device made the largest contribution of the tablet newspaper life cycle (e.g. around 85% of total CO₂eq. emissions). In contrast, in our study content production (emerging version) or electronic distribution (mature version) was the major contributor. However, the former study examined a newspaper rather than a magazine and key assumptions included a reading time of 30 minutes per day and 50% of the overall use time being devoted to reading the newspaper [22]. These assumptions naturally led to a higher share of the manufacturing environmental impacts than our study, where 0.20 and 1.3% of the overall use time of the tablet was allocated to reading the magazine for the emerging and mature versions, respectively. It should also be noted that in the former study, data on content production were limited only to electricity and heat, compared with the more detailed data used in our study. The electronic distribution data in their study were also limited and uncertain.

Comparing the tablet magazine with the traditional print magazine was not in the scope the present paper. However, the potential climate change impact of traditional print magazine has been studied in previous studies. For example, a Finnish study [24] resulted in 1.14-1.35 kg CO₂eq. /kg magazine, and a Swedish study in 0.99 kg CO₂eq. /kg magazine [17].

4.3 Limitations and future work

As with all LCAs, some data were missing or uncertain in the present study. The limitations assumed to be most important are discussed below.

4.3.1 Limitations in inventory of content production

Regarding the electronic equipment used in the office for content production, there are uncertainties associated with the data for manufacturing, which are rather old. Generic data were used for the manufacturing of electronic devices and these data were from the period 2002-2005.

4.3.2 Limitations in inventory of electronic distribution

The data relating to the components used to model the tablet manufacturing were also old and rather uncertain. Based on the components found in a tablet device, data for similar components in the Ecoinvent database [14] were used to estimate the climate impact related to manufacturing.

4.3.3 Limitations in inventory of waste treatment

Waste management of the office electronic devices was not modelled in this study. Waste management of tablets is currently unknown and here assumptions based on communications with a recycling company were used as estimates. Other data on recycling and incineration were taken from Ecoinvent (Swiss, European or global data).

Overall, the results of the study give an indication of the potential climate change impacts of a tablet magazine. Further studies are needed to examine the environmental impacts in more detail and to elaborate upon user practices for this medium.

5. CONCLUSIONS

With few readers, the emerging tablet version had a higher potential climate change impact per reader than the mature tablet version, although the latter had a substantially longer reading time per copy.

For the tablet edition, content production tended to be the major contributor to the climate change impact, especially when readers were few (here for emerging version). With more readers, electronic distribution became a relatively more important contributor. Low overall use time of the device in the mature version resulted in tablet manufacturing being the main contributor to climate impact.

Key factors influencing the overall results for the potential climate change impact of the tablet magazine proved to be number of readers, electricity mix used and overall use of tablet.

Using generic data for the electronic components of the tablet provided more comprehensive data sets, but these were not specific to the actual product studied. However, as environmental data are not provided to any extent or with good transparency for these types of products by the manufacturers, this type of estimation is often necessary.

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