KTH Centre for Sustainable Communications

Screening environmental life cycle assessment of printed, web based and tablet e-paper newspaper

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Åsa Moberg was the project leader. Together with Martin Johansson she performed the LCAs and wrote most of the report. Göran Finnveden and Alex Jonsson contributed with their expertise and wrote minor parts of the report. Åsa is working at both STFI-Packforsk, together with Martin, and at the division of Environmental Strategies Research at KTH together with Göran. Alex is working at the department of Media Technology and Graphic Art at KTH. In addition, Alex, Göran and Åsa are all heavily involved in the Centre for Sustainable Communications at KTH.

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Summary

Viable alternatives for regular newspaper have been available for roughly three years, and often referred to as electronic paper, e-paper or e-readers. These products are meant to carry many of the qualities of paper, such as reading using reflective light, high resolution, 180° viewing angle, high contrast. These properties, along with its notably low power consumption, distinguishes the e-paper displays from devices relying on more traditional display technology, such as the LCD, CRT or plasma screen components.

When an e-paper is used instead of a printed newspaper, the paper, the printing and the physical distribution of the printed paper is avoided. The e-paper device has substantially lower energy use during downloading and reading as compared to using a computer for reading newspapers on the web. Thus, it has been suggested that the environmental impact can be lower than for printed and web based newspapers. However, a life cycle perspective covering raw material acquisition, production, use and disposal, should preferably be used to study the environmental performance of the products. In this way the shift of environmental impact from one part of the life cycle to another can be avoided.

The aim of the present study was to describe the potential environmental impacts of three studied product systems; printed newspaper, web based newspaper and tablet e-paper newspaper. A screening lifecycle assessment (LCA) was performed, aiming to draw conclusions on the potential environmental impacts of the three studied newspaper systems. Another aim of the study was to identify data gaps and areas where more information is needed. This is relevant in particular for the tablet e-paper, which is a new product.

Sundsvalls Tidning (ST) was used as model newspaper, as this Swedish newspaper has been produced and distributed as a printed newspaper, a web based newspaper and a tablet e-paper newspaper. ST has performed a full scale test with an iRex Iliad e-paper device, and thus could provide important input to this study. The scope of the study was firstly to study a newspaper from a European perspective; with European electricity mix and waste flows, etc. In addition, a Swedish scenario was tried.

The studied printed newspaper product system covered energy used for editorial work, production of paper, transportation of paper, production of plates, ink etc for printing, printing, distribution of newspapers and the waste management of disposed newspapers.

For the web based newspaper product system the energy used for editorial work, formatting, down-loading and reading the information on a home computer was included. Furthermore, the production and waste management of PC and screen was to some extent covered.

In the product system tablet e-paper newspaper energy used for editorial work, formatting, up-loading to a server, down-loading and reading the information on a tablet e-paper was included. The production of the tablet e-paper was covered using screening data where the component mix was taken from the electronic component configuration

of a personal computer motherboard and the e-ink screen was not included due to lack of data. Waste management of the waste electronic device was to some extent included.

The LCA covered several different environmental impact categories; global warming, acidification, eutrophication, ozone layer depletion, photooxidant formation and resource use as well as toxicological impact categories. In addition the results were weighted using two different weighting methods; Ecotax 02 and Eco-Indicator 99.

The results showed different patterns regarding where in the life cycle the main potential environmental impact can be seen. For the printed newspaper the main activity was the paper production, for the web based newspaper the energy for reading was crucial and for the tablet e-paper newspaper the production of the electronic device contributed the most to the potential environmental impact. Overall it can be noted that the energy used for editorial work was an activity that also contributes to the total impact. The figure used for energy used for editorial work did not include journalist field work. Environmental impacts from the distribution of the printed newspaper were significant, but not dominant for the results.

A comparison was made between the different product systems. The comparison was made for a European and a Swedish scenario. In the comparison two versions were used for the web based newspaper. Firstly, one where the web based newspaper was read for 10 minutes and 2.5 MB were downloaded and secondly, another where the reading time was increased to 30 minutes (the same time as assumed for reading the printed and e-paper newspapers) and 5.5 MB were down-loaded.

The comparison regarding the global warming impact category (Figure 1) indicated that the web based newspaper (30 min) had the largest contribution in the European scenario (35 kg CO_2/year and unique reader) followed by the printed newspaper. The difference between the web based (10 min) and the tablet e-paper newspapers was rather small.

In the Swedish scenario, the printed newspaper had the largest global warming potential. The web-based newspaper had a lower global warming potential than the e-paper newspaper when 10 minutes of reading was assumed.

The ranking from an environmental point of view was in general that tablet e-paper and the web based newspaper with a shorter reading time (10 min), was giving rise to a lower environmental impact than the printed version. With a reading time of 30 minutes/day the environmental impact of the web based newspaper was in general in the same range as the printed newspaper environmental impact.

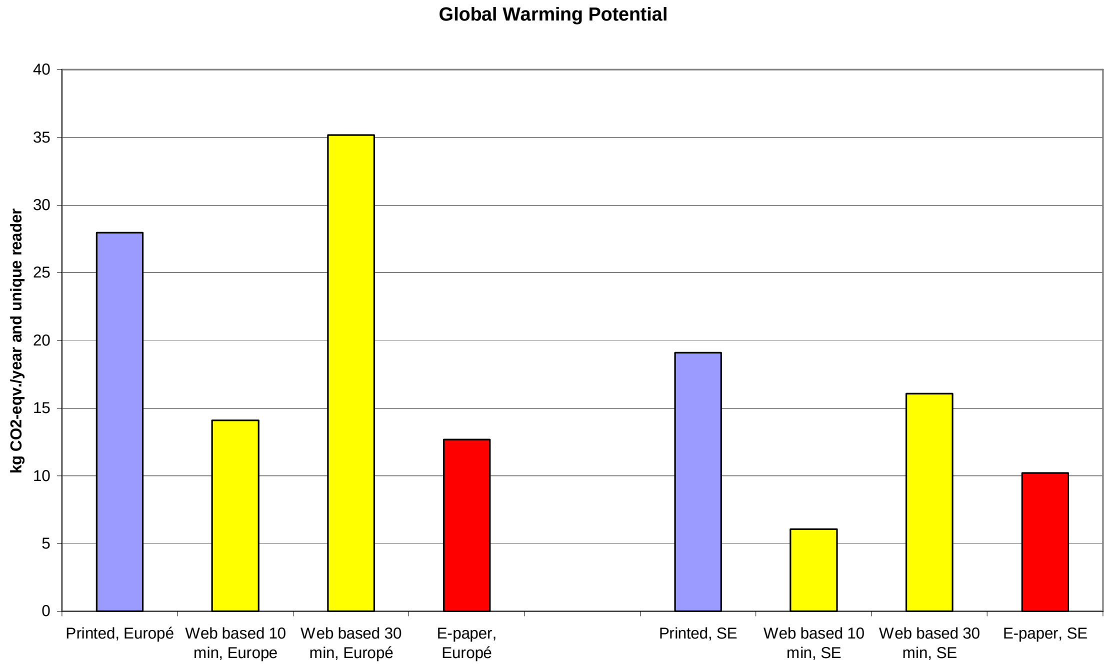


Figure 1. Comparison between printed newspaper, web based newspaper (reading time 10 and 30 minutes) and tablet e-paper newspaper. The comparison regarded global warming potential, and the systems were compared within the European and Swedish scenarios.

Some key aspects which may affect the resulting environmental performance of a newspaper product system were identified:

- Number of readers per copy of printed and tablet e-paper newspapers
- Reading time for web based newspaper
- Lifetime of electronic devices
- Multi-use of electronic devices

In addition it was concluded that tablet e-paper has a potential for decreasing environmental impact of newspaper consumption.

It should however be noted that this study was a screening LCA and conclusions drawn from the study should reflect this. There were some missing data in this screening LCA study. The major activities that were missing are the following:

- Journalist fieldwork (e.g. transportation)
- Production of tablet e-paper e-ink screen
- E-infrastructure
- Recycling of electronic waste

In addition, there are data missing for the use and emissions of hazardous chemicals.

Sammanfattning

Praktiska alternativ till den vanliga dagstidningen i pappersformat har funnits i ungefär tre år, och bär handelsnamn som e-papperstidning, elektronisk dagstidning eller läsplattor. E-pappersskärmar är utvecklade så att de ska innefatta många av papperets kvaliteter, såsom att man läser med reflekterande ljus från omgivningen, hög upplösning, 180-graders läsvinkel och hög kontrast. Dessa egenskaper tillsammans med en låg energianvändning vid användandet utmärker e-pappersskärmar från elektroniska produkter som baseras på traditionell bildskärmsteknik, t ex teknik för en LCD-; CRT- eller plasmaskärm.

Om en dagstidning på läsplatta med e-pappersskärm ersätter en papperstidning kan man undvika fleras teg i traditionell tidningsproduktion; pappersproduktion, tryckning efterbehandling och fysisk distribution av tidningen. E-papper har påtagligt lägre energianvändning vid nedladdning och läsning jämfört med användning av en dator för att läsa tidningen på Internet. Tack vare detta har det antagits att miljöpåverkan kan minskas genom att läsa en tidning på e-papper istället för på papper eller på webb. För att bedöma miljöpåverkan av en produkt eller tjänst bör man dock anta ett livscykelperspektiv, det vill säga ta hänsyn till hela livscykeln från råvaruutvinning, produktion och användning till avfallshantering. I och med detta kan man undvika att miljöpåverkan som sker i en del av livscykeln överförs till en annan.

Syftet med denna studie har varit att beskriva den potentiella miljöpåverkan från tre produktsystem; papperstidning, webb-baserad tidning och en tidningsupplaga med e-papper som informationsbärare. Förenklad livscykelanalys (LCA) utfördes för att kunna beskriva dessa systems totala miljöpåverkan och var i respektive livscykel betydande miljöpåverkan sker. Ett andra syfte med studien var att identifiera var det finns dataluckor och områden där det behövs mer information. Detta är särskilt relevant för e-pappersläsplattan som är en ny produkt.

Sundsvalls Tidning (ST) redaktionella produkter användes som utgångspunkt för delar av studien, eftersom ST har producerats och distribuerats som papperstidning, som Internetbaserad tidning och även som tidning för e-pappersläsplatta. ST har utfört ett fullskaletest där en e-pappersläsplatta, en iRex Illiad, använts och därigenom kunde vi få värdefull information från ST även i denna distributionskanal.

Studien har först och främst utförts med ett europeiskt perspektiv, med europeisk el-mix, europeiska avfallshanteringsströmmar, etc. Dessutom har ett svenskt scenario studerats.

Produktsystemet för papperstidning har inkluderat energianvändning för redaktionellt arbete, pappersproduktion, transport av papper, produktion av tryckplåtar, färg och annat som behövs för tryckning, tryckning, distribution av tidning samt avfallshantering av tidning.

Produktsystemet för den webbaserade upplagan har inkluderat energianvändning för redaktionellt arbete, formatering, nedladdning och läsning av tidningen på en hemmadator. Dessutom har produktion och avfallshantering av hemmadator och skärm inkluderats till viss del.

Produktsystemet för tidning på läsplatta med e-pappersskärm har inkluderat energianvändning för redaktionellt arbete, formatering, nedladdning på server, nedladdning till användarens läsplatta och läsning av tidningen på läsplattan. Dessutom inkluderades produktion av läsplattan genom att ungefärliga data användes, bland annat användes komponentsammansättningen hos en vanlig dators moderkort användes som modell. Produktion av läsplattans skärmdel med inkapslade färgartiklar (från USA-baserade E-ink) saknas på grund av databrist. Avfallshantering av läsplattan hanterades till viss del inom studien.

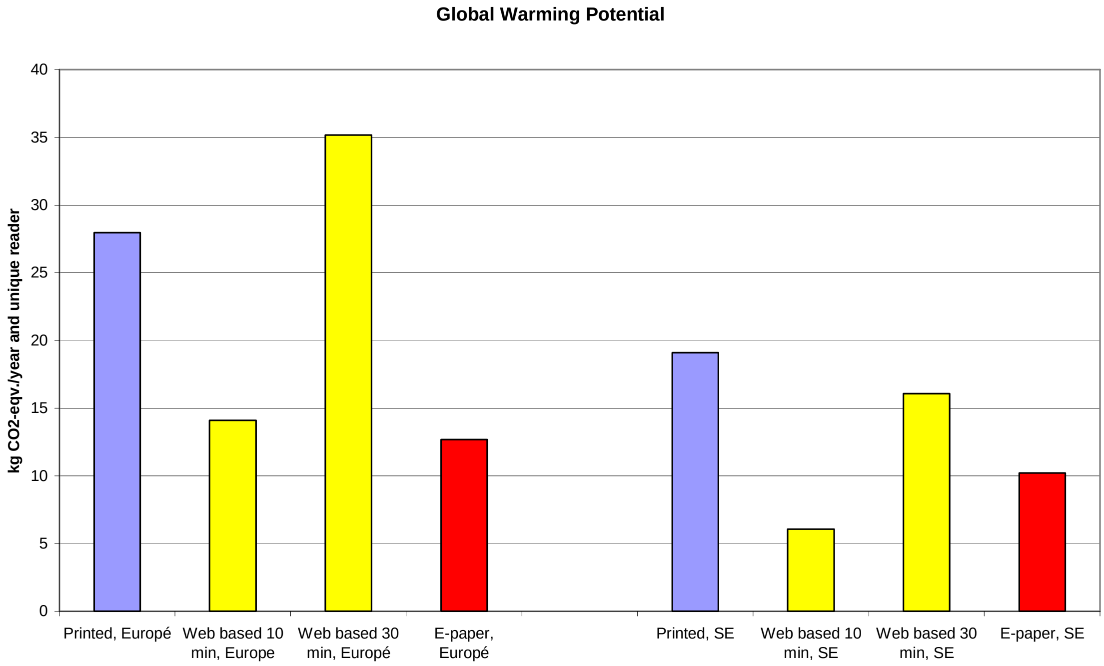
Livscykelanalysen täckte in ett antal miljöpåverkanskategorier: växthuseffekt, försurning, övergödning, ozonnedbrytning, bildning av fotokemiska oxidanter samt påverkanskategorier för resursutnyttjande och toxikologisk påverkan. Dessutom viktades resultaten samman på två olika sätt med hjälp av två olika viktningsmetoder; Ecotax 02 and Eco-Indicator 99.

Resultaten visade på olika miljöbelastning från olika aktiviteter i de respektive produktsystemens livscykler. För papperstidningen stod pappersproduktionen för den mest betydande andelen av miljöpåverkan, för den Internetbaserade tidningen var energianvändningen vid läsning avgörande och för tidningen på e-pappersläsplatta stod produktionen av själva läsplattan för den största delen av miljöpåverkan. Generellt kan det också noteras att energianvändningen för redaktionellt arbete märkbart bidrog till den totala miljöpåverkan i flera fall. Denna energianvändning inkluderade inte journalisternas fältarbete. Distribution av papperstidningen var av betydelse för resultaten, men inte dominerande.

En jämförelse gjordes mellan de olika produktsystemen. Jämförelsen gjordes i ett europeiskt scenario och i ett svenskt scenario. I jämförelsen användes två olika versioner av Internetbaserad tidning. Dels en version där tidningen antogs läsas i 10 minuter och 2,5 MB laddades ner, dels en version där tidningen antogs läsas i 30 minuter (samma lästid som antagits för de två andra systemen) och där 5,5 MB laddades ned.

För påverkanskategorin växthuseffekt (Figur 2) visade jämförelsen i det europeiska scenariot att den Internetbaserade tidningen med 30 minuters lästid medförde den största påverkan (35 kg CO_2/år och unik läsare) åtföljd av papperstidningen. Skillnaden mellan den Internetbaserade tidningen med 10 minuters lästid och tidningen på e-pappersläsplatta var liten.

I det svenska scenariot hade papperstidningen den största påverkan i form av växthuseffekt. Den Internetbaserade tidningen med 10 minuters lästid hade i detta fall lägre påverkan än tidningen på e-pappersläsplatta.



Figur 2. Jämförelse mellan papperstidning, webb-baserad tidning (lästid 10 och 30 min) och tidning på läsplatta med e-pappersskärm. Jämförelsen gällde växthuseffekt i ett europeiskt och ett svenskt scenario.

Generellt rankades tidningen på läsplatta med e-pappersskärm och den webb-baserade tidningen med en lästid på 10 minuter som mindre miljöbelastande än papperstidningen. Med en längre lästid (här 30 minuter/dag) var miljöbelastningen från den Internetbaserade tidningen generellt i samma spann som papperstidningen.

Några antaganden som kan vara avgörande för resultatet i en studie av miljöprestanda för olika produktsystem för tidning identifierades:

- Antal läsare per papperstidningsexemplar och per e-pappersläsplatta
- Lästid för Internetbaserad tidning
- Livstid för elektroniska produkter
- Användning av elektroniska produkter för flera olika syften

Dessutom drogs slutsatsen att e-pappersläsplattan har potential för att minska miljöbelastningen för en dagstidning.

Denna studie var en förenklad LCA och det bör reflektera de slutsatser man drar från studien. Ett flertal dataluckor identifierades också, däribland:

- Journalistiskt fältarbete (t.ex. transporter)
- Produktion av läsplattans skärm
- Infrastruktur för elektronisk distribution
- Återvinning av elektroniskt avfall

Vidare så finns det dataluckor för användning och emissioner av farliga ämnen.

1 Introduction

1.1 Background

Viable alternatives for regular newspaper have been available for roughly three years (Jan 2004), and often referred to as electronic paper, e-paper or e-readers. These products are meant to carry many of the qualities of paper, such as reading using reflective light, high resolution, 180° viewing angle, high contrast. These properties, along with its notably low power consumption, distinguishes the e-paper displays from devices relying on more traditional display technology, such as the LCD, CRT or plasma screen components. Apart from the display itself, the e-readers consist mostly of standard components, such as a plastic housing, a low-power one-chip microprocessor, rechargeable battery, controller boards and implements for navigation, such as buttons, jog wheels or stylus for browsing through your household electronic newspaper edition. Some of the devices also carry an on-board wireless radio transceiver to automatically download the latest edition on demand, which makes them similar in usage to a cellular phone, only with about ten times bigger screen.

There are several patented methods on how to create and sustain an image on the e-paper device, of which E-ink Technology (MIT start-up, founded in 1997) represents the most widespread to date. Other companies with similar ideas, such as Epson and Bridgestone, have yet to market their products in early 2007.

A crash course on the technology involves a 200 microns thin plastic laminate sandwiching microcapsules containing both black (carbon) and white (titanium dioxide) particles that are attracted to a negative or positive charge respectively (Figure 3). Once an image is established, the static charge is held without consuming power for hours and days until the image is updated again, when “flipping” to the next page.

Figure 3. Principle of electronic paper, courtesy of E-ink Technology.

Several device manufacturers, such as Sony, Motorola, Jhinke and iRex use the e-paper substrate for their products, the Sony E-reader, the iRex Iliad, the Hanlin eBooks as well as Motorola's Motofone F3, which in fact is a cell phone targeting the Indian market with a sales price of less than $100. The e-paper screen on-board contributes heavily to the F3's excellent performance with seven hours usage or near 17 days on standby on a single battery charge.

Figure 4. The iRex Iliad, courtesy of iRex.

For the iRex Iliad (shown in Figure 4), the fact that the device only consumes power at updates, and also that only parts of the page can be targeted, allows the device to carry out over 7500 page flips before the Iliad needs to dock with its charging device. This particular device is also subject to the full-scale test carried out at Swedish daily newspaper Sundsvalls Tidning, as potentially viable alternative to reading the morning newspaper either on paper or off a computer screen through the newspaper's website.

When a tablet e-paper is used instead of a printed newspaper, the paper, the physical distribution of the printed paper, etc are avoided. The e-paper device has substantially lower energy use during downloading and reading as compared to using a computer for reading newspapers on the web. Thus, it has been suggested that the environmental impact can be lower than for printed and web based newspapers. However, a life cycle perspective should preferably be used to study the environmental performance of the products. In this way the shift of environmental impact from one part of the life cycle to another can be avoided.

1.2 Life cycle assessment-general

1.2.1 Introduction

Life Cycle Assessment (LCA) is a method to assess the potential environmental impacts and resources used throughout a product's life from raw material acquisition through production, use and disposal. The term 'product' can include also services. An ISO standard has been developed for LCA providing a framework, terminology and some methodological choices (ISO, 2006). An LCA is divided in four phases (Figure 5): Goal and Scope Definition, Inventory Analysis (which is a compilation of the inputs and the outputs of the system (Rebitzer et al, 2004), Life Cycle Impact Assessment (LCIA), and Interpretation. The result from the Inventory analysis is a compilation of the inputs (resources) and the outputs (emissions) from the product over its life-cycle in relation to the functional unit. The latter is a description of the functions that the product (or service) provides. All results in an LCA are related to this functional unit. In comparative studies, the definition of the functional unit is essential so that the alternatives are compared on a fair basis.

The LCIA phase is divided into several elements, some of which are regarded as optional (ISO, 2006). The first elements of the LCIA (Classification and Characterisation) are based on more or less traditional natural science and aim at describing the contribution from the studied system to a number of environmental impact categories such as resource depletion, human health impacts and ecological consequences. One of the optional elements of LCIA is called weighting and includes a valuation of different impact categories against each other. This may include different types of monetisation methods or multi-criteria decision analysis techniques (Pennington et al, 2004). In this step different types of values are required and natural science alone is thus not enough.

There are two different types of LCA, accounting or attributional LCA and consequential or effect-oriented LCA (see e.g. Baumann and Tillman, 2004). In attributional LCA a system is described as it is. In consequential LCAs, the consequences of a choice are modelled. These two types of LCA use different types of data. The accounting type of LCA uses data for the processes which are used. This means that different types of average data should be used, for example for the energy system. In consequential LCAs, which reflect the changes, data reflecting processes affected by these changes should be used. This normally means some sort of marginal data.

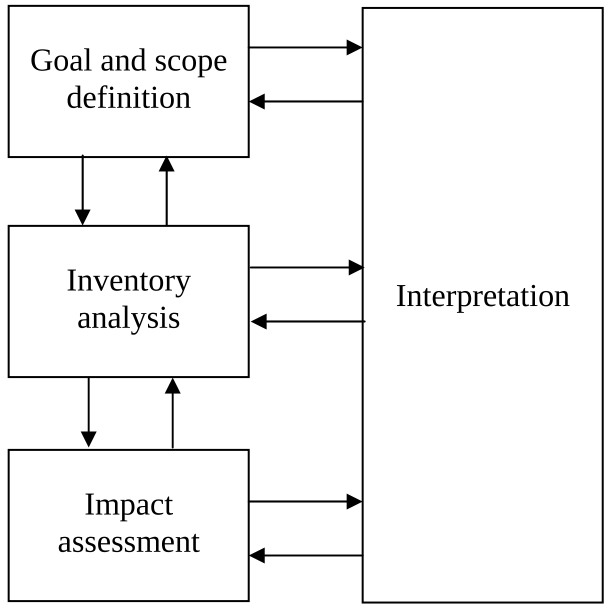


Figure 5. A Life Cycle Assessment consists of four phases.

1.2.2 Allocation and system expansion

Life Cycle Assessment is one example of an environmental systems analysis tools (Finnveden and Moberg, 2005). As in all types of systems analysis, the question of system boundaries is essential. There are three major types of system boundaries that are essential (Guinée, 2002):

1) between the technical system and the environment
2) between significant and insignificant processes
3) between the technical system under study and other technical systems.

In relation to the first system boundary, it can be noted that an LCA should cover the entire life-cycle. Thus the inputs should ideally be traced back to raw materials as found in nature. For example, crude oil can be an input, but not diesel oil since the latter is not found in nature, instead it is produced within the technical system. In parallel, the outputs should ideally be emissions to nature.

The second system boundary is further discussed in section 1.2.3.

The third system boundary results in so called allocation problems. They occur when a process is shared between several product systems and it is not clear to which product the environmental impacts should be allocated.

One example of an allocation problem is related to waste treatment and recycling. Consider a printed newspaper. In the waste management phase it can for example be incinerated with energy recovery. In this case, the waste treatment serves two purposes: taking care of a waste problem and producing a new product: heat and/or electricity. If we are doing an LCA on newspapers, one may thus consider if the incineration plant should be considered a part of the newspaper lifecycle or a part of the lifecycle of heat and electricity or both.

There are two principally different ways of handling this type of allocation problems. One is to allocate (partition) the environmental impacts between the two products (newspaper and energy). This can be done on the basis of several principles e.g. physical causation or economic value. The other principle to solve the allocation problem is to avoid it by expanding the system boundaries and include both products in the system model. In this approach the emissions from the incineration are included in the product system, but an alternative competing source for energy is also included in the system model. It is then assumed that the energy from the newspaper incineration can replace energy from the competing source, which thus is avoided. The environmental impacts from the competing energy source are then subtracted from the environmental impacts from incineration of the waste paper. In this way the newspaper system is credited for also producing heat and/or electricity. If the paper is recycled instead of incinerated, the recycled material can replace paper from other sources. In the same way as for incineration, the newspaper system can then be credited for avoiding the production of paper from other sources.

The ISO-standard gives some guidance on how to handle allocation problems. It states that whenever possible system expansion should be used to avoid allocation problems. If that is not possible, an allocation reflecting the physical (or chemical or biological) causations should be used, and finally if that is not feasible allocation based on other measures, e.g. economic value, may be used.

Recycling of materials can occur in two different ways: closed-loop and open-loop. In closed-loop recycling, the material is used to produce the same type of product again. An example can be glass which is used to produce glass. In closed-loop recycling, the modelling of the whole loop can be made within the studied product system and no allocation problems will occur. In open-loop recycling, the material is used to produce another type of product. One example is waste fine paper which is recycled into newsprint.

1.2.3 Screening LCA – general

A full LCA can be time consuming and resource extensive. Instead of starting with a full LCA, an alternative approach can be to perform a screening LCA with the aim of identifying the most important aspects of the studied system. If wanted, more detailed studies can then be directed to these important aspects (Lindfors et al, 1995).

A screening LCA is usually performed using easily accessible data. Since the aim is to identify the most important processes, data quality is of less importance than in a full LCA. It is important however to include all processes and materials that can be of major importance. If however some processes or materials are known to be of minor importance, they can be excluded.

A special type of easily accessible data comes from so called environmentally extended input-output analysis (IOA). Input-output analysis is a well-established analytical tool within economics and systems of national accounts (Miller and Blair, 1985). Input-output matrixes describe trade between different sectors and industries in society. In this way, it can for example be seen how much a specific industry (say food industry) is buying from other industries (agriculture, machinery, transportation etc). These industries are in their turn buying from other industries which in turn are buying from other industries etc. Through mathematical manipulations, the whole picture can however be described so that the total amount of products and services that are inputs from all industries in order to produce an output from a specific industry can be calculated.

Environmental information can be added to the IOAs by adding emission intensities for the different sectors. The emission intensities are expressed as emissions per monetary unit. Through the same type of mathematical manipulations, the upstream emissions to produce a certain amount of products from a specific industry can be calculated. In this way, environmental impacts from industries and broadly defined product groups can be calculated.

1.2.4 Some earlier studies of relevance

Several studies of the environmental impact of printed media and paper have been made (e.g. Larsen et al 2004; Johansson 2002; Axel Springer Verlag AG et al. 1998; Axelsson and Dalhielm 1997). Web based newspaper reading has been compared to reading of printed news in earlier studies (Yagita et al, 2003; Hischier and Reichart, 2001). Other kind of information in printed or electronic for has also been compared from an environmental perspective (Gard and Keoleian, 2002). E-paper newspaper has been compared to printed an on-line newspaper in one earlier study found, and this study was only published in German (Kamburow 2004). The study of Kamburow concerned cumulative energy use (Kumulierten Primärenergieaufwandes, KEA).

The potential environmental impact of the production, use and waste management of electronic equipment has been studied (e.g. Atlantic Consulting and IPU, 1998; Choi et al., 2006; Lu et al., 2006). Andrae et al (2005) went through previous LCAs of electronics and they state that there is a lack of representative component and material data for LCA use. In some cases they find it hard to reveal whether intermediate manufacturing processes are included in the case studies made. Andrae et al emphasise that the intermediate upstream processes may in the adding up of impacts be significant.

1.3 Aim and scope

The aim of the project presented in this report was to describe the potential environmental impacts of the three studied product systems; printed newspaper, web based newspaper and tablet e-paper newspaper. A screening LCA was performed, aiming to draw conclusions on the potential impacts. The results illuminate which activities, i.e. parts of the respective product systems that are most important from an environmental point of view. In addition, the results provide the opportunity to compare the potential environmental impact of the three studied products systems, given the assumptions made.

Another aim of the study was to identify data gaps and areas where more information is needed. This is relevant in particular for the tablet e-paper, which is a new product.

Sundsvalls Tidning (ST) was used as model newspaper, as this Swedish newspaper has been produced and distributed as a printed newspaper, a web based newspaper and a tablet e-paper newspaper. ST has performed a full scale test with an iRex Iliad e-paper device, and thus could provide important input to this study. A major part of the newspaper data defining the three studied product systems are from ST, for example edition, number of pages and number of readers. The scope of the study was firstly to study a newspaper from a European perspective; with European electricity mix and waste flows, etc. In addition, a Swedish scenario was tried.

1.4 Guide to the reader

In chapter 2 the scope and the methodology used in this study are described. The systems studied are presented and major assumptions and missing data are noted. This chapter lays the ground for the interpretation of the quantitative results. In chapter 3 characterised and weighted results are presented. In addition, all results of the impact assessment can be found in Appendix 4. Chapter 3 may be heavy to read from A to Z. It can be preferable to look for particular results or to jump back and forth between chapter 3 and 4. Finally, in chapter 4 the results of the study are discussed, conclusions drawn and some suggestions on interesting future research are made.

2 Scope and methodology of this study

Three different product systems were studied; printed newspaper; web based newspaper and tablet e-paper newspaper. The product systems studied are described below as well as major preconditions and assumptions made. Some specific processes are described, since they were regarded as important (i.e. editorial work, electricity and heat). The product systems were firstly studied with a European perspective (a European reader). In this scenario a European electricity mix was used, as well as European waste flows. Urban distribution was assumed, with lower fuel consumption per printed newspaper than in the Swedish scenario. In the Swedish scenario a Nordic electricity mix and Swedish waste flows were used. The main scenario was decided to be European to give more general results than a Swedish scenario would. The Swedish scenario, as well as a scenario where parts of the web based newspaper is printed, is described following the European scenario. The scope and methodology of the study is further presented at the end of this chapter.

2.1 Printed newspaper – European scenario

The printed newspaper that was studied here is described in Table 1. The data were mainly based on information from Sundsvalls Tidning. The amount of copies and readers have been estimated from the current edition (Boström, personal communication 2006) and the assumption that 2 000 readers will change to tablet e-paper. The geographical boundary used was Europe and the paper used was assumed to be European average 45 g/m^2 DIP (de-inked pulp) containing newsprint. The reading time, 30 minutes, was based on information from the Swedish Newspaper Publishers' Association (TU, 2006). The reading time of the newspaper does not affect the environmental assessment, but is an important aspect of the benefit of the printed newspaper. The possible extra light needed for reading the printed newspaper was not included in this study.

Table 1. Description of the studied printed newspaper

Parameter	Printed newspaper
Edition	32 000 copies/day, 6 days/week
Size	40 pages
Format	Tabloid ($40x28cm^2$)
Number of readers	76 000 unique readers/day (2.4 readers per copy of newspaper)
Basic weight of paper	$45g/m^2$
Paper	Newsprint DIP (de-inked pulp) containing
Reading time	30 minutes/day
Distribution	Urban distribution

The functional unit of this product system was the yearly consumption of newspaper for a unique reader (see 2.10.1) and it equals 131 newspapers/year (312 newspapers/year and 2.4 unique readers/newspaper).

In the European scenario the assumption was that the content production, the production of paper, the use phase and the waste management were taking place in Europe.

In Figure 6 the process plan for the printed paper, as illustrated in the Gabi software used, is shown. The grey boxes represent underlying process plans with the same principle structure of coupled processes.

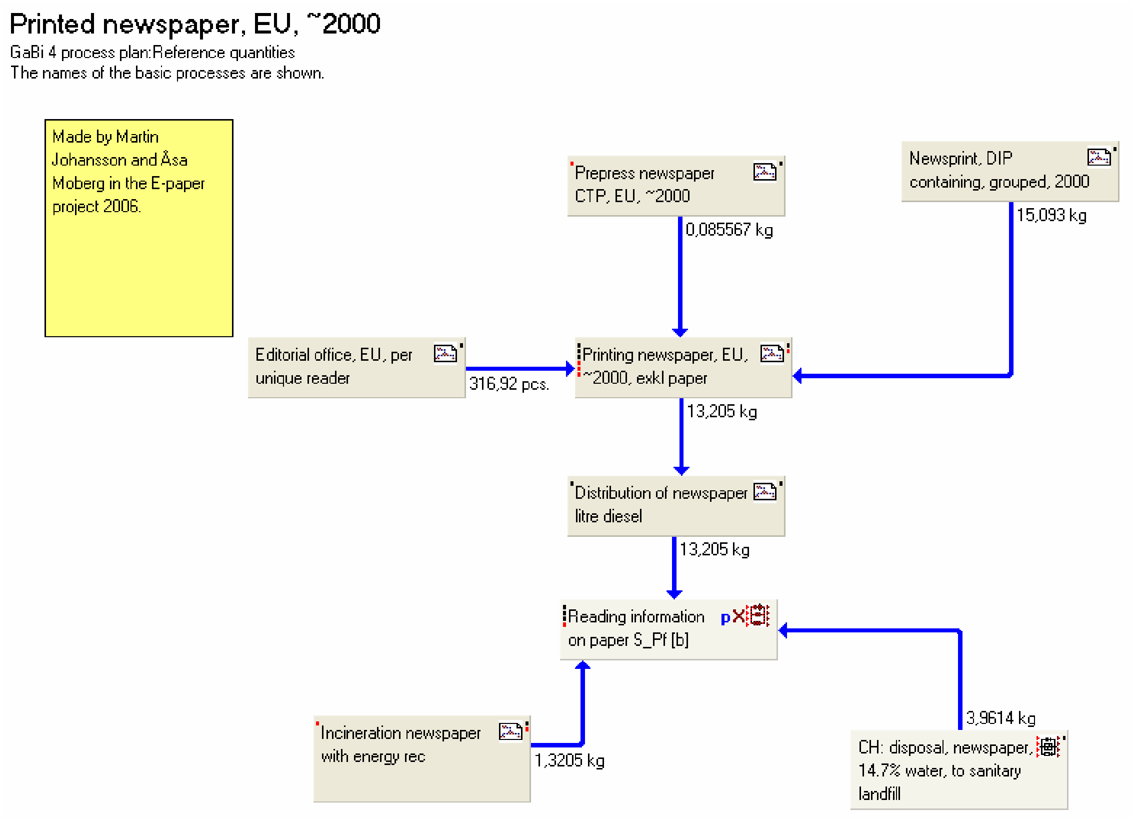


Figure 6. Process plan for the printed newspaper product system.

The analysis has a full life cycle perspective. In the data one step back are presented, the rest of the upstream and downstream processes are presented in Appendix 1. The journalist fieldwork (e.g. transportation) was not included in the analysis.

Table 2 The life cycle of printed newspaper was modelled. This table only presents data one step back. The rest of the upstream and downstream processes are presented in Appendix 1.

Process	Input	Description	Source of data
Newsprint DIP containing	Newsprint DIP	Newsprint containing de-inked pulp (DIP) from post consumer recycled paper. The dataset is based on several European LCA studies made 2000-2002. The used electricity mix in the process is Nordel 45%, UCTE 45% and GB 10% (for a description of the mixes, see 2.5.1). Raw material consumption for 1kg paper: ▪ 744 g wood (140% moisture) ▪ 302 g wood chips (70% moisture) ▪ 18 g sulphate pulp ▪ 757 g waste paper for DIP	Ecoinvent 1.2
Transportation of paper	Train	Transport, freight, rail, including the entire transport life cycle. Data from 2000. Represents average transport conditions in Europe (EU15).	Ecoinvent 1.2
	Lorry	Transport, lorry, 32 t., including the entire transport life cycle. Data from 2000. Represents average transport conditions in Europe (EU15).	
Prepress		Data from LCA studies by STFI-Packforsk (former IMT/Framkom) on Swedish newspapers 1995-2002. The older data sets have been adapted to current plate production technology, computer to-plate (CTP).	STFI-Packforsk
	Electricity	A mix of the three electricity systems UCTE, Nordel and GB. In the European scenario 76:12:12 (for a description of the mixes, see 2.5.1). Electricity, medium voltage, production UCTE, at grid. Electricity, medium voltage, production Nordel, at grid. Electricity, medium voltage, production GB, at grid.	Ecoinvent 1.2
	Gumming	EU average 2000. Only data on energy use.	STFI-Packforsk

Process	Input	Description	Source of data
	Offset plate	Production of offset plate, EU average 2002.	STFI-Packforsk
		Data on aluminium from Ecoinvent 1.2. Plate from 68% virgin aluminium. The waste plates were assumed to be recycled into new plates (closed-loop). The amount of recycled aluminium which will not be part of the loop (approximately 68%) was recycled (Aluminium, secondary, from new scrap, at plant) and credited through avoided production of aluminium from virgin resources (Aluminium primary at plant).	Ecoinvent 1.2
	Plate developer	EU average 2000. Only data on energy use.	STFI-Packforsk
Editorial work		Data from LCA studies by STFI-Packforsk (former IMT/Framkom) on Swedish newspapers 1995-2002. Total energy needed for the editorial office. Heat and electricity used are not separately reported and the total energy use was modelled as electricity.	STFI-Packforsk
	Electricity	See Prepress/Electricity.	
Printing		Data from LCA studies by STFI-Packforsk (former IMT/Framkom) on Swedish newspaper companies 1995-2002.	STFI-Packforsk
	Electricity	See Prepress/Electricity.	
	Ink	Data from earlier LCA performed by STFI-Packforsk (former IMT/Framkom) on ink 1998-2002. Based on Swedish production data with European electricity mix.	STFI-Packforsk
	Isopropanol (IPA)	Data on Nafta production in Sweden, 1993. Allocation to the part of the production that represents IPA and Cleaning agent respectively.	STFI-Packforsk
	Cleaning agent	See Printing/IPA.	
	Water	EU average 2000, tap water at user.	Ecoinvent 1.2
Distribution		Average data from Swedish newspaper companies 2005 (Mint project) divided into urban and rural distribution.	STFI-Packforsk
	Transport	Small transporter/3.5t total cap./2t payload local, German data from 1995. Only data on emissions of CO_2, CO, dust, methane, NO_x, NMVOC and SO_2 from the use of the van.	GaBi
		Modified by STFI-Packforsk with data for urban distribution in the European scenario, see above.	
	Diesel	Diesel free refinery. German data from 1997.	GaBi

Process	Input	Description	Source of data
Reading		No environmental impact from reading.	
Incineration with energy recovery		Modified data from Ecoinvent 1.2; “Disposal, newspaper, 14.7% water, incineration CH”. Including avoided energy production. Net energy produced through incineration of waste paper: • electric energy: 1.32 MJ/kg waste • thermal energy: 2.77 MJ/kg waste The avoided energy production (68% heat and 32% electricity) was assumed to replace European mixes of electricity and heat (see 2.5). Data on avoided electric energy see Prepress/Electricity. Data on avoided thermal energy from: ▪ Hard coal, Germany 1996, GaBi data ▪ Natural gas, Germany 1996, GaBi data ▪ Light fuel oil, Germany 1996, GaBi data ▪ Wood, EU 1996, BUWAL data in GaBi database	Ecoinvent 1.2 GaBi GaBi GaBi BUWAL
Landfill		Swiss data for landfilling, without energy recovery, “Disposal, newspaper, 14.7% water, to sanitary landfill CH”. The time perspective for emissions from the landfill was 100 years.	Ecoinvent 1.2
Recycling of fibre		Closed-loop recycling (impacts of recycling included in the process “Newsprint DIP containing”.	

2.1.1 Major assumptions

The major assumptions made for modelling of the printed newspaper are summarised in Table 3.

Table 3. Major assumptions made when modelling the printed newspaper product system.

Field of assumption	Assumption made
Transportation of paper	Assumed distances: 400 km by truck and 1600 km by train, European average. These assumptions were based on Ecoinvent 1.2.
Distribution	Assumed vehicle: van, 3.5 tonnes, payload 2 tonnes, local use. Data from an internal STFI-Packforsk database (Mint) gave estimations on fuel consumption for urban distribution: 0.0043 litre fuel/newspaper.
Recycled fibre and waste management of post-consumer waste paper	The paper waste streams, based on European statistics on waste paper recovery for 2005 (CEPI, 2006): • 60% recycling • 30% landfill • 10% incineration Recycling of newspaper was modelled as closed-loop. Landfill was modelled without energy recovery. Incineration was modelled with energy recovery.

The offset plate used in the prepress was assumed to be made out of 68% virgin aluminium. This was based on European average data from European Aluminium Association (EAA) used in the Ecoinvent 1.2 database. The recycled aluminium was treated as closed-loop. The amount of recycled aluminium which was not part of the loop (approximately 68%) was modelled as recycled and credited through avoided production of aluminium from virgin resources.

2.2 Web based newspaper – European scenario

The web based newspaper that was studied is described below. The figures on readers per day and size of the electronic newspaper were from Sundsvalls Tidning (Boström, personal communication, 2006). The reading time of 10 minutes per day was based on Holsanova and Holmqvist (2004). Data on down-loading and power of electronic equipment were assumptions made based on information on average equipment.

Table 4. Description of the studied web based newspaper

Parameter	Web based newspaper
Edition	7 days/week
Size	2.5 MB/day
Number of readers	8 000 unique readers/day
Computer power	160 W
Screen power	120W
Down-loading speed	0.25 MB/s (2 Mbits/s)
Reading time	10 minutes/day

The functional unit of this product system, the yearly consumption of newspaper for a unique reader (see 2.10.1), equals 913MB/unique reader and 61 hours of reading/unique reader

In the European scenario the assumption was that the content production, the production of paper and the use phase were in Europe, the production of the computer and screen in China and the waste management in Europe. The process plan is shown in Figure 7.

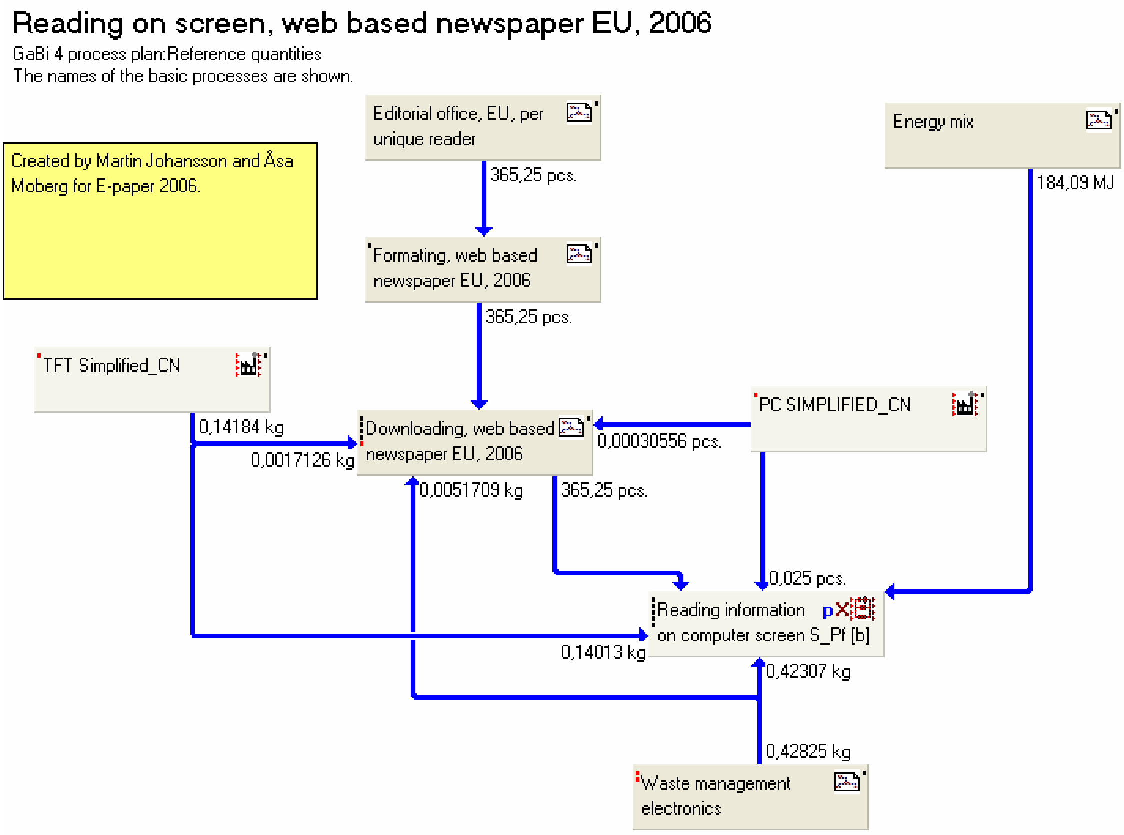


Figure 7. Process plan for the web based newspaper product system.

The analysis has a full life cycle perspective. In Table 5 the data one step back are presented, the rest of the upstream and downstream processes are presented in Appendix 1. Main processes not included in the study were the journalist fieldwork (e.g. transportation), construction of infrastructure and use of infrastructure for electronic distribution and material recycling of parts of the waste computer and screen.

Table 5. The life cycle of web based newspaper was modelled. This table only presents data one step back. The rest of the upstream and downstream processes are presented in Appendix 1.

Process	Input	Description	Source of data
Editorial office	Electricity	Total energy needed for the editorial office. Heat and electricity used are not separately reported and the energy use was modelled as electricity. A mix of the three electricity systems UCTE, Nordel and GB. In the European scenario with the ratio 76:12:12 (for a description of the mixes, see 2.5.1). Electricity, medium voltage, production UCTE, at grid. Electricity, medium voltage, production Nordel, at grid. Electricity, medium voltage, production GB, at grid.	Ecoinvent 1.2
Formatting web based newspaper	Electricity	Energy needed for formatting. See description of electricity above.	Ecoinvent 1.2
Downloading web based newspaper	Electricity	Energy needed for down-loading the newspaper to the home computer. See description of electricity above.	Ecoinvent 1.2
Production PC		The dataset contains screening life cycle inventories (LCIs) of the devices: • Housing • Drives (Hard disc drive, Floppy, CD-Rom) • PCI cards (Graphic card, Sound card, Network card) • Power supply module and cables • Populated Motherboard The reference year is 2002. No transportation or distribution included. According to LBP, in the context of a screening LCA most relevant flows are captured.	LBP, University of Stuttgart

Process	Input	Description	Source of data
Production TFT screen		The dataset contains screening life cycle inventories (LCIs) of the devices: • Stand (ABS/PC parts, Steel Sheet) • Power Supply Unit (PSU) (populated printed wiring boards, PWB) • Housing (ABS/PC parts) • Backlight assembly (PMMA, Steel, Polyester, Glass) • LCD Panel • Metal Frames • Soundcard (populated PWB) • Inverter (populated PWB) • Other PWBs • Other parts (Steel, PS, PVC, PE, Copper) For all assemblies, except the LCD panel, the most important material production and average manufacturing processes are considered, according to LBP. For the LCD panel the electricity consumption for manufacturing processes and clean room are considered. The reference year is 2002. Transportation and distribution are not included. According to LBP, in the context of a screening LCA most relevant flows are captured.	LBP, University of Stuttgart
Transportation of PC and screen		Transport from China to European user.	Ecoinvent 1.2
	Ship	Transport, transoceanic tanker, including entire transport life cycle. Data from one port in Netherlands as an estimate for international water transportation. HFE based steam turbine and diesel engines.	
	Lorry	Transport, lorry, 32 t., including the entire transport life cycle. Data from 2000. Represents average transport conditions in Europe (EU15)	
Energy use for Reading information on computer screen	Electricity	Energy needed for the computer and screen while reading the newspaper. See description of electricity above.	Ecoinvent 1.2

Process	Input	Description	Source of data
Waste management electronics	Disposal, plastic, consumer electronics, with energy recovery	Incineration of waste (100% plastics from electronic consumer goods) with energy recovery. "Disposal, plastic, consumer electronics, 15.3% water, to municipal incineration" modified by STFI-Packforsk. Upper heating value 36.29 MJ/kg; lower heating value 34.78 MJ/kg. Net energy produced through incineration of waste plastics: • electric energy: 4 MJ/kg waste • thermal energy: 8.05 MJ/kg waste One kg of this waste produces 0.037 kg of slag and 0.019 kg of residues, which are modelled as landfilled. Material recycling of waste PC and screen were not covered due to lack of data.	Ecoinvent 1.2

2.2.1 Major preconditions and assumptions

Major assumptions made for the modelling of the web based newspaper product system are listed in Table 6.

The formatting time of 4 hours was based on information from Sundsvalls Tidning (Boström, personal communication 2006).

It was assumed that a home computer (PC and screen) was used and that this computer was used in total 4 hours per day on an average. In Jönbrink and Amen (2006) a compilation of studies of computer use patterns are presented. The range of active use time for a home computer is in the compilation from two to six hours per day. The PC and screen were assumed to be produced in China and the transportation of the equipment from China to Europe was assumed to be by boat and truck. Distances were roughly estimated (see Table 6).

The life time of the computer was assumed to be 5 years (Wendschlag, personal communication 2007). The information concerning life time originated from studies made by Hewlett Packard, covering 50 tonnes of waste products at four waste recyclers in Europe. In a review of consumer behaviour Jönbrink and Amen (2006) present average economic lifetimes of total life of 6-7 years (first life 5-6 years).

According to Sverker Sjölin at Stena Technoworld, a major part of computers are recycled (personal communication 2006). As an average figure Sjölin suggests that 30% of a home computer is incinerated and that this share consists of mainly plastics. The rest of the computer is recycled into metal, plastics and glass. This division is proposed, by Sjölin, to be the same for Europe and Sweden. Jönbrink and Amen (2006) suggest another distribution of waste fractions for Sweden: 80% to recycling; 15% to incineration; 4% deposition and 1% destruction. In this study 70% recycling and 30% incineration was used. The assumption that the European situation was the same as the Swedish may be an overestimation of recycling and an underestimation of landfill. Jönbrink and Amen (2006) consider the municipal waste management in Europe as an approximation of management of waste electronics, and in this perspective the landfill option is clearly underestimated in this study. However, this is about to change as the WEEE directive comes into force. The levels to be met for IT and telecommunications equipment and consumer equipment, according to the Directive, are 75% recovery (e.g. incineration with energy recovery and material recycling) and 65 % recycling (Directive 2002/96/EC). As we have no better figures for Europe and at the same time LCI data on recycling and landfill of electronics were not easily available, in the study the same division of waste streams of electronics for Sweden and Europe was assumed.

Table 6. Major assumptions made when modelling the web based newspaper product system.

Field of assumption	Assumption made
Formatting content for web edition	4 hours/day assumed for formatting the web based newspaper.
Transportation of PC and screen	Boat 15 000 km, estimated distance China – Europe. Truck 500 km, assumed distance by truck in Europe.
Home computer and screen	Total use time: 4 hours/day Life time: 5 years
Waste management of computer and screen	70% material recycling and 30% incineration (plastics)

2.3 Tablet e-paper newspaper – European scenario

2.3.1 Description

The product system tablet e-paper newspaper is a new system still under development. Sundsvalls Tidning has performed a trial where some of their readers were using a tablet e-paper for reading the newspaper. Some of the data used here are from Sundsvalls Tidning. Data for this product system was relatively hard to access within the scope of this study. Many of the processes were estimated and the uncertainties are relatively large. The e-paper product system would be interesting to study in more detail.

The tablet e-paper newspaper that was studied here is described below. The figure on readers per day was based on an assumption made by Svenåke Boström at Sundsvalls Tidning (personal communication 2006). This was an approximation of a probable scenario in 5 years time. The reason for not studying the situation as it is today was that this scenario would not be feasible, i.e. a tablet e-paper newspaper system including only the around ten readers that were part of the trial. The e-paper newspaper was sent to the readers twice a day in this case. That was why the e-paper newspaper had a daily edition of 5 MB, compared to the 2.5 MB of the web based newspaper.

Technical data regarding the e-paper device (e.g. power) were data for the iRex Illiad tablet e-paper device used by Sundsvalls Tidning. Data on the server power and uploading speed was based on estimations. Reading time per day was assumed to be the same as for a printed newspaper, 30 minutes (TU, 2006).

Table 7. Description of the studied tablet e-paper newspaper

Parameter	Tablet e-paper newspaper
Edition	7 days/week
Size	5 MB/day (2.5 MB two times per day)
Number of readers	2000 unique readers /day
Server power	900 W
Up-loading speed (server)	3 MB/s (24Mbits/s), (0.0025 MB/day and reader)
E-paper power (down-loading)	0.75W
Down-loading speed	0.25 MB/s (2 Mbits/s)
E-paper power (reading)	0.001W
Reading time	30 minutes/day

The functional unit of this product system, the yearly consumption of newspaper for a unique reader (see 2.10.1) equals 1830 MB/unique reader and 183 hours of reading/unique reader.

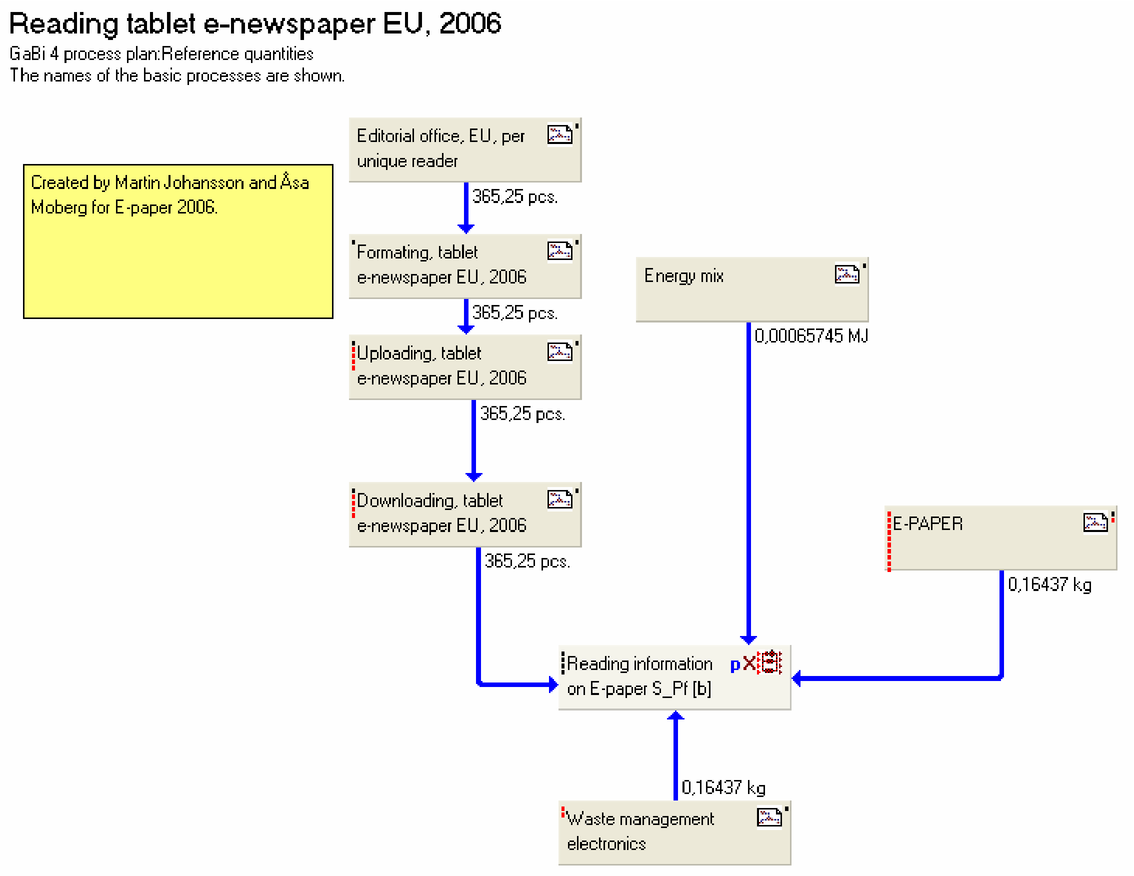


Figure 8. Process plan for the tablet e-paper newspaper product system.

In the European scenario the assumption was that the content production and the use phase was in Europe, the production of the tablet e-paper in China and the waste management in Europe. The process plan of the studied system is shown in Figure 8.

The analysis had a full life cycle perspective. In Table 8 the data one step back are presented, the rest of the upstream and downstream processes are presented in Appendix 1. Main processes that were not included were the journalist fieldwork (e.g. travel), construction of infrastructure and use of infrastructure for electronic distribution and material recycling of parts of the waste e-paper device.

Table 8. The life cycle of tablet e-paper newspaper was modelled. This table only presents data one step back. The rest of the upstream and downstream processes are presented in Appendix 1.

Process	Input	Description	Source of data
Editorial office	Electricity	Total energy needed for the editorial office. Heat and electricity used were not separately reported and the energy use was modelled as electricity. A mix of the three electricity systems UCTE, Nordel and GB was used. In the European scenario 76:12:12 (for a description of the mixes, see 2.5.1). Electricity, medium voltage, production UCTE, at grid. Electricity, medium voltage, prod. Nordel, at grid. Electricity, medium voltage, production GB, at grid.	Ecoinvent 1.2
Formatting tablet e-newspaper	Electricity	Energy needed for formatting. See description of electricity above.	Ecoinvent 1.2
Uploading tablet e-newspaper	Electricity	Energy needed for up-loading the newspaper to a central server, which distributes the newspaper electronically to tablet e-paper readers. See description of electricity above.	Ecoinvent 1.2
Downloading tablet e-newspaper	Electricity	Energy needed for down-loading the newspaper to the e-paper device. See description of electricity above.	Ecoinvent 1.2
Production tablet e-paper		The model was based on available data, see below. The e-paper model consists of two assemblies: • Display module (Voyager) • Base module (Illiad) For the PWBs (printed wiring boards) the component mix was taken from the electronic component configuration of a personal computer motherboard. Assembly specific manufacturing processes, transportation and distribution were not included. The E-ink screen was not included. The Chinese power grid mix was used for all production processes (see specification in 2.5.1). According to LBP, in the context of a screening LCA most relevant flows were captured.	LBP University of Stuttgart

Process	Input	Description	Source of data
Transportation of tablet e-paper device.		Transport from China to European user.	Ecoinvent 1.2
	Ship	Transport, transoceanic tanker, including entire transport life cycle. Data from one port in Netherlands as an estimate for international water transportation. HFE based steam turbine and diesel engines.	
	Lorry	Transport, lorry, 32 t., including the entire transport life cycle. Data from 2000. Represents average transport conditions in Europe (EU15).	
Energy use for Reading information on e-paper	Electricity	Energy needed for the e-paper while reading the newspaper. See description of electricity above.	Ecoinvent 1.2
Waste management electronics	Disposal, plastic, consumer electronics, with energy recovery	Incineration of waste (100% plastics from electronic consumer goods) with energy recovery. “Disposal, plastic, consumer electronics, 15.3% water, to municipal incineration” modified by STFI-Packforsk. Upper heating value 36.29 MJ/kg; lower heating value 34.78 MJ/kg; Net energy produced through incineration of waste plastics: • electric energy: 4 MJ/kg waste • thermal energy: 8.05 MJ/kg waste One kg of this waste produces 0.037 kg of slag and 0.019 kg of residues, which was modelled as landfilled. Material recycling of waste e-paper devices was not included due to lack of LCI data.	Ecoinvent 1.2

2.3.1.1 The production and composition of the e-paper device

In this screening LCA we had limited access to data regarding the production and composition of the e-paper device. The data used for the modelling in the LCA software are listed below (Table 9). The modelling was performed by LBP (Lehrstuhl für Bauphysik) at Stuttgart University.

The description was mainly based on information from iRex Technologies BV (Leurs, personal communication 2006). Assumptions on wacomsensor composition and the weight ratio for PWB and components for the Iliad assembly were made in the modelling. As the e-paper device is under development the design and the components are probably bound to change considerably during the coming years, and thus the potential impact will change.

Data on the E-ink screen were largely missing. Information on the pigment (carbon black and titanium dioxide) was used to roughly assess the importance of the e-ink screen. The amounts of carbon black and titanium dioxide were estimated to 15 grams each, which was probably overestimations.

Table 9. LCI data used as input to the modelling of the e-paper device at LBP, University of Stuttgart.

Parts	Material	Weight	Area
Bottom cover	PC/ABS	59.5 g	
Middle frame	PC/ABS	34 g	
Top cover	PC/ABS	30.5 g	
Keys and flipbar	PC/ABS	5.5 g	
Lightguide	PMMA	0.15 g	
Illiad product components			
PWB (incl components) (assumed to be including components, with the same ratio as Voyager; 12.8:6.4)		100 g	0.0255 m^2
Battery, Li-ion		50 g	
Voyager product components			
8 inch display		58.7 g	
PWB		12.8 g	0.00536 m^2
Electronic components		6.4 g	
TCP’s (4*0.13 source + 3*0.3 gate)		1.4 g	
Interconnection foil (incl. components)		0.8 g	
8.1 Wacomsensor		29.88 g	

2.3.2 Major assumptions and limitations

Major assumptions made for the modelling of the tablet e-paper newspaper product system are listed in Table 10.

The assumption of a life time of 1 year was based on an assumption that with the rapid development of this new product there will probably be an actual life time which is shorter than the technical life time. The technical life time is today for the e-paper Illiad at least 4 years, according to Willem Endhoven at iRex Technologies (e-mail to Svenåke Boström 2006). It can be assumed that the life time will increase as the e-paper device gets more mature.

The reading time, 30 minutes per day, was assumed based on the reading time for printed newspaper (TU, 2006). Other use of the e-paper device than for reading newspapers includes reading e-books, e-documents, e-journals, etc. and a rough estimation of the time for other use was 30 minutes per day. This assumption is uncertain, since the tablet e-paper is not yet frequently used and there was no information on user behaviour easily available.

The waste management of the tablet e-paper device was based on the same assumptions as for the waste management of the PC and screen in the web based newspaper product system (see 2.2.1).

Table 10. Major assumptions made when modelling tablet e-paper newspaper product system.

Field of assumption	Assumption made
Formatting content for e-paper edition	4 hours/day assumed for formatting the tablet e-paper newspaper.
E-paper device	The E-ink screen composition and production was not included in the model due to lack of data. The life time was assumed to be 1 year.
Transportation of tablet e-paper device	Boat 15 000 km, estimated distance China – Europe. Truck 500 km, assumed distance by truck in Europe.
Reading time	Time for e-paper newspaper reading: 30 minutes/day. The e-paper device is assumed to be used 30 minutes/day for other purposes than newspaper reading.
Waste management of tablet e-paper device	70% material recycling and 30% incineration (plastics)

2.4 Editorial work

The content production was assumed to be made for a newspaper providing all three products (printed, web based and tablet e-paper newspaper). The energy use (electricity and heat) used for editorial work was split equally between all unique readers, independent on which product they read. The total number of unique readers was assumed to be 86 000 per day (see Table 11). This figure was based on an estimation of the possible situation in 2-5 years, if the tablet e-paper has come into regular use at, in this case, Sundsvalls Tidning. The energy data used for editorial work was from another, smaller newspaper (15 000 copies and 28 pages as compared to 32 000 copies and 40 pages in the studied case). The data included both electricity and heat: 6480 MJ/edition (Lindblad, 2001). In this study the energy use was modelled as electricity only. Specific energy data for Sundsvalls Tidning was not available.

Table 11. The number of unique readers for the three different products respectively.

Product system	Number of readers	Number of copies
Printed newspaper	76 000	32 000
Web newspaper	8 000	
Tablet e-newspaper	2 000	

The main processes part of the editorial work are shown in Table 12.

Table 12. Processes included in the modelling of content.

Process	Input	Description	Source of data
Electricity mix	Electricity, medium voltage, production UCTE, at grid. Electricity, medium voltage, production Nordel, at grid. Electricity, medium voltage, production GB, at grid.	Total energy needed for the editorial office. A mix of the three electricity systems UCTE, Nordel and GB was used. In the European scenario 76:12:12 (for a description of the mixes, see 2.5.1).	Ecoinvent 1.2

The content produced was, in the Gabi software, described as a flow of "pieces of editorial information". In this case, one piece of editorial information equals the amount of content produced and distributed every day. A yearly consumption of newspaper amounts to 365 pieces of editorial information. In the case of the printed newspaper a printed copy is only distributed 312 days per year, as the newspaper is distributed 6 days per week. We assumed that the editorial work done the seventh day was also to the benefit of the readers of the printed version, thus the energy use for editorial work is split equally between all unique readers. However, in the modelling, only 312 pieces of editorial information is used for the yearly production of printed newspaper.

2.5 Energy

Energy is often a significant parameter in environmental assessments of products, therefore electricity mixes and district heating mixes used are described separately in this section.

2.5.1 Electricity

The electricity used in the major processes within the product systems was modelled as a mix of electricity. In the European scenario, this mix was 76% UCTE (Union for the

Co-ordination of Transmission of Electricity), 12% Nordel and 12% electricity produced in Great Britain (GB), based on figures for total production (generation) 2005 (Eurelectric, 2005). In the Swedish scenario 100% Nordel was used. For the different paper production processes the electricity mixes are described in 2.1, 2.2 and 2.8.

UCTE includes electricity production in Austria, Belgium, Bosnia-Herzegovina, Bulgaria, Croatia, Czech Republic, France, FYROM, Greece, Hungary Italy, Luxemburg, Macedonia, Netherlands, Poland, Romania, Serbia and Montenegro, Slovenia, Slovak Republic, Spain and Switzerland.

The resulting composition is presented in Table 13. The composition of energy sources of the electricity produced in UCTE countries was based on information in Ecoinvent 1.2.

Table 13. Energy sources used in the UCTE electricity production.

Energy source	Share in mix
Nuclear	0.36
Coal	0.26
Hydropower	0.16
Natural gas	0.13
Oil	0.07
Industrial gas	0.02
Wind	0.008
Wood	0.003

Nordel includes electricity production in Denmark, Finland, Iceland, Norway and Sweden. The resulting composition is presented in Table 14 (based on Ecoinvent 1.2).

Table 14. Energy sources in the Nordel electricity production.

Energy source	Share in mix
Hydropower	0.61
Nuclear	0.20
Coal	0.07
Natural gas	0.05
Wood	0.04
Oil	0.02
Peat	0.01
Wind	0.01

The composition of energy sources used for electricity production in Great Britain is presented in Table 15 (based on Ecoinvent 1.2).

Table 15. Energy sources in the electricity production in Great Britain.

Energy source	Share in mix
Natural gas	0.40
Coal	0.32
Nuclear	0.22
Hydropower	0.02
Oil	0.02
Industrial gas	0.01
Wood	0.01

For the production of the electronic equipment and its components Chinese electricity mix was used. This mix is described in Table 16 (based on data from LBP, Stuttgart University).

Table 16. Energy sources in the electricity production in China.

Energy source	Share in mix
Coal	0.72
Hydropower	0.18
Oil	0.08
Natural gas	0.01
Nuclear	0.01

2.5.2 Heat

Data for heat production was used to assess the resources and emissions that were avoided through energy recovery (heat and electricity) from incineration of waste paper and waste plastics in the studied product systems. The heat production avoided was assumed to be district heating.

The average energy sources for producing district heating in Europe were roughly estimated using data on output from district heating facilities (Eurostat, 2007) and data on energy sources of district heating in relevant countries (Euroheat and Power, 2007). Data on heat output were from 2004 and data on energy sources were from different years (1997, 1999 and 2000) for different countries. Poland, which has a large output of district heating, was assumed to have the same composition of energy sources for district heating as Germany since there were no specific information regarding Poland available on the Euroheat and Power website. The countries included in the calculated mix were Austria, Bulgaria, Finland, Germany, Lithuania, Poland, Romania and Sweden. This selection was based on information from the website of Euroheat and Power (2007), where these countries have a rather large district heating output and information was available regarding energy sources use (except for Poland).

The district heating mix of energy sources used in the European scenario is shown in Table 17. Heat from waste is approximated by 50% heat from oil and 50% heat from wood, since there were no easily available processes for heat produced from waste in the used databases. Waste constituted 16% of the district heating in the European case.

Table 17. District heating mix used in the European scenario.

Energy source	Share in mix
Coal	0.34
Natural gas	0.34
Oil	0.18
Wood	0.14

In the Swedish scenario another district heating mix was used. The composition of this mix was based on data for 2004 from Svensk Fjärrvärme (2007), see Table 18. Heat from waste is approximated by 50% heat from oil and 50 % heat from wood, since there were no easily available processes for heat produced from waste in the used databases. Waste constituted 15% of the district heating in Sweden 2004. Heat from peat was also approximated by 50% heat from oil and 50 % heat from wood, since there were no easily available processes for heat produced from waste in the used databases. Peat constituted 8% of the district heating in Sweden 2004.

Table 18. District heating mix used in the Swedish scenario.

Energy source	Share in mix
Wood	0.60
Oil	0.22
Coal	0.09
Natural gas	0.08

2.6 Swedish scenario

A Swedish scenario for the product systems was studied in addition. The differences compared to the European scenario concern:

- Electricity mix used for editorial work, formatting, prepress, printing and reading on electronic equipment.
- For production at the paper mill 100% Nordel was used in the Swedish scenario. For production of supply chemicals, wood handling and pulp production the same energy mix as for the European scenario was used.
- Transportation of paper from the mill to the printing house (mode and distance).
- Distribution of printed newspapers was based on data describing rural distribution instead of urban (internal data, STFI-Packforsk).
- Electricity mix and district heating mix used for avoided energy production.
- Waste management flows (i.e. share of waste paper to recycling, incineration and landfill respectively).

The electricity mix used in the Swedish scenario was 100% Nordel as specified in 2.5.1. This electricity mix was used for all processes taking place in Sweden in the Swedish scenario where a change of data was possible. Concerning the production of supply chemicals for the pulp and paper production, wood handling and sulphate pulp production the same energy mix as in the European scenario was used also in the Swedish scenario, as these data were aggregated and the energy use could not be altered. The electricity used for internal pulp and paper production (integrated mill) was changed to 100% Nordel. Some production processes were performed outside of Sweden, also in the Swedish scenario. Examples included the production of PC, screen and tablet e-paper device produced in China and gumming, offset plate, plate developer and ink for the printing process produced in Europe. These processes were not changed compared to the European scenario.

The transportation of paper from the paper mill to the printing house was in the European scenario assumed to be performed with truck and diesel train. In the Swedish scenario the transportation was assumed to be shorter and the modes to be truck and electric train. Transport distances were assumed to be 250 km by truck and 250 km by electric train. These assumptions were based on Ecoinvent 1.2 data on average transport distances and means from paper mill to printing facilities within one country. The electric train LCI data only included data for the operation of the train, an average European electro traction goods train (Ecoinvent 1.2), i.e. the entire transportation life cycle was not included.

The distribution of printed newspaper was in the Swedish scenario assumed to be a rural distribution. Data from an internal STFI-Packforsk database (Mint) was used. For rural distribution the fuel consumption was estimated to be 0.015 litre fuel/newspaper, as compared to 0.0043 litre fuel/newspaper in the European scenario.

The district heating mix used to model the avoided heat production in the Swedish scenario is described in 2.5.2. Waste management of waste paper in Sweden was assumed to be 80% to material recycling and 20% to incineration with energy recovery (based on data from FTI, 2007).

2.7 Including internet infrastructure scenario

In one scenario the construction and use of infrastructure for distributing the newspapers electronically (web based and e-paper) was included. The available data for Internet infrastructure were from SimaPro USA Input Output database 98 (PRe´, 2003). This database consists of commodity data from 1998 supplemented with data for capital goods. The data used covered “telephone, telegraph communications, and communications services n.e.c.”. In the database manual (PRé, 2003) it is stated that for some sectors, including the information technology (IT) sector these data have probably changed a lot during the last years. Thus, the results concerning potential impact of using telecommunication infrastructure are too uncertain to draw any real conclusions from. The data was anyhow used to get an indication on whether the infrastructure in this case may be of importance or not.

A rough assumption made when using these data was that the production cost for using 1 MB use of the infrastructure was 0.1 Euro/MB. This assumption was made based on information from Spray (a Swedish telephone and internet company) on the cost for using internet, in their case SEK 1.49 per MB during 2006, which was roughly translated into € 0.1 per MB. Better data on the actual cost could not be found within the scope of this study.

Table 19. Assumptions made concerning the internet infrastructure.

Field of assumption	Assumption made
Internet infrastructure	Production cost 0.1 €/MB

Only the major emissions were transferred from the US input-output (IO) database to the Gabi software used in this project. The selection was made based on quantity. This way of selecting outputs may lead to missing out on important emissions of smaller quantities but with significant impact. However, since these data were anyhow uncertain the effort of including the dataset was limited by making this selection.

The inputs and outputs included from the “telephone, telegraph communications, and communications services n.e.c.” data from (PRé, 2003) are listed in (Table 20).

Table 20. Inputs and outputs included in the process Infrastructure Telecommunications, based on input-output data from SimaPro USA Input Output database 98.

Inputs	Outputs
Copper ore	Carbon dioxide
Crude oil	Carbon monoxide
Hard coal	Methane
Iron ore	Nitrogen dioxide
Natural gas	Sulphur dioxide
Sand	VOC
Conventional arable land	
Industrial area	

2.7.1 Other infrastructure

For the paper production, electricity and heat production and waste management; infrastructure (machinery and equipment) was included in the inventoried system. For other production, infrastructure was not included in the data, e.g. printing presses. For transportation different data were used. In some cases infrastructure was included in the data and in some not, this is described in the respective tables describing which processes make up the studied systems.

2.8 Web based newspaper with print-out scenario

In one scenario the web based newspaper reading was complemented with a print-out of two A4-pages per day. Assumptions regarding the amount of printing of the web based newspaper on a home printer were rough estimations to give an illustration of the effect of printing.

Table 21. Description of the studied web based newspaper with print-out

Parameter	Tablet e-paper newspaper
Printer power	300 W
Printer speed	0.25 m^2/minute, one side
Printing amount	2 A4/day, one sided
Basic weight of paper	80g/m^2
Paper	Uncoated woodfree paper from virgin fibre
Paper waste	5%

The functional unit of this product system, the yearly consumption of newspaper for a unique reader (see 2.10.1) equals 913MB/unique reader, 61 hours of reading/unique reader and 730 A4 sheets/unique reader.

The additional processes, as compared to the web based newspaper in the European scenario (2.2) are shown in Table 22 and assumptions made in Table 23. The analysis has a full life cycle perspective. In Table 21 the data one step back are presented, the rest of the upstream and downstream processes are presented in Appendix 1. Main processes that were not included were the production, transportation and waste management of the printer.

Table 22 Additional processes included in the modelling of web based newspaper when print-out was assumed. This table only presents data one step back. The rest of the upstream and downstream processes are presented in Appendix 1.

Process	Input	Description	Source of data
Uncoated woodfree paper		Uncoated wood free paper for the home printer. Wood free means that this paper contains at least 90% of the fibres in form of chemical pulp. The dataset is based on several European studies made 2000-2002. The used electricity mix in the process is UCTE 64%, Nordel 27%, and GB 9% (see description in 2.5.1). Raw material consumption for 1kg paper: ▪ 1985 g hardwood (80%moisture) ▪ 1228 g softwood (140% moisture) ▪ 236 g wood chips (70% moisture) ▪ 35 g sulphate pulp	Ecoinvent 1.2
Laser home printing		Printing using an hp colour LaserJet 4550. This process includes energy use for computer and screen for reading and printing.	STFI-Packforsk
	Ink, Cyan; Magenta; Yellow; Black;	Toner production data from Xerox, 2001. Only input data. No energy use included.	STFI-Packforsk
	Electricity	A mix of the three electricity systems UCTE, Nordel and GB; 76:12:12. Electricity, medium voltage, production UCTE, at grid. Electricity, medium voltage, production Nordel, at grid. Electricity, medium voltage, production GB, at grid.	Ecoinvent 1.2

Process	Input	Description	Source of data
Reading		No environmental impact from reading.	
Incineration with energy recovery		Modified data from Ecoinvent 1.2; “Disposal, newspaper, 14.7% water, incineration CH”. Including avoided energy production. Net energy produced through incineration of waste paper: • electric energy: 1.32 MJ/kg waste • thermal energy: 2.77 MJ/kg waste The avoided energy production (68% heat and 32% electricity) was assumed to replace European mixes of electricity and heat (see 2.5). Data on avoided electric energy see prepress/electricity. Data on avoided thermal energy from:	Ecoinvent 1.2
		▪ Hard coal, Germany 1996, GaBi data	GaBi
		▪ Natural gas, Germany 1996, GaBi data	GaBi
		▪ Light fuel oil, Germany 1996, GaBi data	GaBi
		▪ Wood, EU 1996, BUWAL data in GaBi database	BUWAL
Landfill		Swiss data for landfilling, without energy recovery, “Disposal, newspaper, 14.7% water, to sanitary landfill CH”. The time perspective for emissions from the landfill is 100 years.	Ecoinvent 1.2
Recycling of fibre		The part of the fine paper that is recycled was assumed to replace newsprint produced from virgin fibre.	
	Paper recycling with deinking	Newsprint production from recovered fibre. Includes de-inking process, paper machine, on-site energy production, flue gas cleaning technology and waste water treatment plant. The dataset is based on several European studies made 2000-2002. The used electricity mix in the process is UCTE 100% (see description in 2.5.1). Raw material consumption for 1kg paper: ▪ 1173.4 g recovered paper	Ecoinvent 1.2

Process	Input	Description	Source of data
	Avoided newsprint production	Newsprint production from virgin fibre. The dataset is based on several European studies made 2000-2002. The used electricity mix in the process is UCTE 44%, Nordel 45%, and GB 10% (see description in 2.5.1). Raw material consumption for 1kg paper: ▪ 1428 g wood (140%moisture) ▪ 1048.9 g wood chips (70% moisture) ▪ 25.7 g sulphate pulp	Ecoinvent 1.2

Table 23. Assumptions made for the scenario where part of the web based newspaper was printed on a home printer.

Field of assumption	Assumption made
Waste management of post-consumer waste paper	For the European scenario the paper waste streams were (CEPI, 2006): • 60% recycling, • 30% landfill • 10% incineration Recycled paper was assumed to replace newsprint from virgin fibre. The landfill option was modelled without energy recovery. Incineration was modelled with energy recovery.

2.9 Comparison between printed, web based newspaper and tablet e-paper newspaper

A comparison between the three product systems was made (Figure 9). In the comparison two versions of the web based newspaper product system was included. The average reading time, which was 10 minutes for web newspaper, was complemented with a product system with 30 minutes of reading. In the 30 minutes case the down-loading was estimated to be 5.5 MB/day, as compared to 2.5 MB/day for the 10 minutes reading case.

Figure 9. Images of the three newspaper versions studied.

It may be discussed whether the same reading time would be used irrelevant of the media; printed, web based or tablet e-paper if only one of them was to be used. If this was the case, then the comparison of the same reading times would be more relevant. However, it can be argued that the web based newspaper fulfil a different function (Holmqvist et al, 2003 and Holsanova and Holmqvist 2004), which involves a shorter reading time.

In the comparison we have included printed newspaper (reading time 30 minutes), web based newspaper (reading time 10 minutes), web based newspaper (reading time 30 minutes) and tablet e-paper newspaper (reading time 30 minutes).

2.10 Scope and methodology of the study

2.10.1 Functional unit

The functional unit of the study was "*the consumption of newspaper during one year by one unique reader*". The three product systems were studied separately and no combinations were made within the scope of this study (e.g. the reading of web based newspaper combined with a printed version).

2.10.2 System boundaries

The study was a screening LCA. Easily available data was used and this resulted in some missing data. These were noted in the respective description of the studied systems above.

The geographical system boundaries of the study were, in two different scenarios, Europe and Sweden respectively for the use phase. These system boundaries affect the electricity mix used in production and use phase, the transportation of paper from mill to printing house, the distribution of newspaper, the district heating mix used and the waste flow to different waste management options.

The time boundary for landfilling of waste paper was set to 100 years in the Ecoinvent 1.2 process used.

The study covers the current situation, but concerning the readers of tablet e-paper newspaper a future scenario, about five years, was used to estimate a situation where a tablet e-paper may be used in a larger scale. The current situation for the tablet e-paper would not have been relevant to study, since this product is not used in a relevant scale.

2.10.3 Expanded systems

In the cases where waste management was performed through material recycling or incineration with energy recovery, the product systems were expanded to include avoided products (see explanation in 1.2.2). This was the case for waste newspaper which was recycled or incinerated, waste fine paper (from home printing of web based news) which was recycled or incinerated and electronic waste which was incinerated. The avoided products for each case are described in 2.1, 2.2, 2.3, 2.6 and 2.8.

2.10.4 Data quality and uncertainty

Where possible, data from established databases, such as Ecoinvent 1.2, and internal databases at STFI-Packforsk were used.

Data for the construction and use of infrastructure for electronic communication was from SimaPro USA Input Output database 98, which consist of data from 1998 (PRe´2003). In the database manual (PRé, 2003) it is stated that for some sectors, including the information technology (IT) sector these data have probably changed a lot during the last years. We, anyhow, used these data to get an indication on the possible importance the infrastructure.

To our knowledge, there were no previous studies of the environmental impact of tablet e-paper. Information regarding the composition of the tablet e-paper was provided by iRex Technologies (Leurs, personal communication 2006). This information was used as input to the screening modelling of this device. For the PWBs (printed wiring boards) the component mix was taken from the electronic component configuration of a personal computer motherboard. Data for the tablet e-paper e-ink screen were missing.

Screening data were used for the production of a PC and a TFT screen (LBP, Stuttgart University).

Regarding the waste management of electronics, average data for incineration of home electronics (plastic parts) were used. There were no easily available data on the material recycling of waste electronics, thus these data were missing. In the case of waste management of the tablet e-paper the same proportion as for the PC was assumed to be recycled and incinerated respectively. However, a more thorough analysis of the product would be needed to clarify the waste management procedure for the tablet e-paper.

2.10.5 Missing data

Some data were missing; this was mainly due to the fact that there were no easily available data. The missing data include the following:

- Journalist fieldwork (e.g. travel)
- Production of tablet e-paper e-ink screen
- E-Infrastructure
- Recycling of electronic waste

In further studies these areas should preferably be covered.

2.10.6 Life cycle impact assessment

2.10.6.1 Characterisation methods

In the characterisation step all inventoried data are assigned values to make aggregation to a single score within a specified impact category possible (see 1.2.1). For the impact assessment the characterisation methods listed below were used.

Resources used were characterised using:

- Abiotic Depletion Potential, ADP (CML2001, as listed in GaBi ver 4.112)
- Exergy in resources (abiotic resources and biotic resources) as listed in EcoTax 02, (Eldh 2003).
- Energy in resources (non-renewable/abiotic, renewable and total resources) as listed in EcoTax 02, (Eldh 2003)

Non-toxicological impacts were characterised using:

- Acidification Potential (CML2001 as listed in GaBi ver 4.112)
- Eutrophication Potential (CML2001 as listed in GaBi ver 4.112)
- Global Warming Potential, no biotic CO_2 (GWP 100 years) (Modification of CML2001 as listed in GaBi ver 4.112 where biotic CO_2 is set to zero)
- Ozone Layer Depletion Potential , steady state (CML2001 as listed in GaBi ver 4.112)
- Photochem. Ozone Creation Potential (CML2001 as listed in GaBi ver 4.112)

Toxicological impacts were characterised using:

- Freshwater Aquatic Ecotoxicity Potential (CML2001 as listed in GaBi ver 4.112)
- Human Toxicity Potential (CML2001 as listed in GaBi ver 4.112)
- Marine Aquatic Ecotoxicity Potential (CML2001 as listed in GaBi ver 4.112)
- Terrestric Ecotoxicity Potential (CML2001 as listed in GaBi ver 4.112)

Most of the characterisation methods are thus identical to the baseline set in the Dutch guidelines for LCA (Guinée, 2002). The exception concerns resources where we have added the thermodynamic approach where resources are measured in terms of exergy (Finnveden and Östlund, 1997) and a measures of the energy use.

2.10.6.2 Weighting methods

Two different weighting methods, described below, were used in the study.

<u>Eco-Indicator 99 Hierarchist Approach</u>

The method uses a model to assess the average damage in Europe from different environmental aspects. Instead of looking at specific condition for each emission or resource, average conditions for Europe are used. In a first step the environmental impact from different emissions and resource use are characterised to environmental load using natural science. Three impact categories are used, ecosystem health, human health and resource use. In the next steps European data on exposure and effects are used to calculate the effect to the three impact categories. As a last step a weighting procedure, based on cultural values based on distance-to-target (a low damage level) are applied. Three cultural perspectives are represented in the method, individualist (short-term, conservative), egalitarian (long term, precautionary) and hierarchist ("middle way") (Goedkoop and Spriensmaa, 2000). In this study the hierarchist approach was used for the Eco-indicator method as implemented in the Gabi software.

<u>Ecotax 02 minimum and maximum</u>

Ecotax is a monetary method where the weighting is based on environmental taxes and fees in Sweden. The method was developed 1998 (Johansson, 1999) and updated 2002 (Eldh, 2003, Finnveden et al, 2006). The weighting is done using existing impact categories by linking a tax or fee on a relevant substance to the impact category to get a reference equivalent weight. I.e. tax on CO_2 is used as reference for Global Warming Potential. In this report the categorisation method CML 2001 was used complemented with exergy data on resources, see section 2.10.6.1.

The Ecotax method has two alternative weighting factors, minimum (min) and maximum (max), representing the span of taxes and fees on various substances within the same impact category. Both versions were used in this study.

2.10.7 LCA software

The analyses were done using the LCA software GaBi, version 4.112, a software developed by PE International GmbH.

In the GaBi software, plans, processes and flows and their functionalities establish modular units. Data of inventory, impact assessment, and weighting models are separated. When analysing a life cycle of a product the processes included are connected in a graphical interface in a so called process plan, see Figure 6, Figure 7 and Figure 8. Process plans can also be analysed in several layers, where a process plan can be illustrated as a "single process" in another process plan.

3 Results and discussion

3.1 Introduction

Results from the inventory analysis that are not from previously documented sources are presented in Appendix 2 and 3.

The results presented in this chapter are from characterisation and weighting of the inventoried data. The results are described and a selection is illustrated in diagrams. All characterised and weighted results are presented in Appendix 4. The characterisation and weighting methods used are presented in 2.10.6.

In the result presentation below, for resources used the focus was on ADP (abiotic depletion potential), abiotic exergy and total energy in resources used. In the appendix, the results for biotic exergy and renewable and non-renewable energy in resources used can also be found. The ADP and the abiotic exergy impact categories show the use of non-renewable resources and the total energy in resources used include non-renewable and renewable resources.

It should be noted that the uncertainties were large for the toxicological impact categories. There were knowledge gaps which make it difficult to characterise toxicological impacts, and there were many data gaps concerning toxicological emissions in the data inventories. It is still important to include toxicological impacts, but to be aware of the uncertainties.

3.2 Printed newspaper

3.2.1 European scenario

3.2.1.1 Resources used

For the printed newspaper in the European scenario the impact categories ADP, abiotic exergy and total energy gave similar results (Figure 10). The newsprint production was the main activity concerning resource use, followed by the printing of the newspaper. In addition, editorial work, prepress, paper transport and distribution were activities that contributed to the total resources used. The paper transport was in the European case assumed to be long distance (2 000 km) and the transport modes were diesel freight train and truck. The distribution was assumed to be performed with a van in urban areas, i.e. with lower fuel consumption per newspaper than the rural distribution assumed in the Swedish scenario.

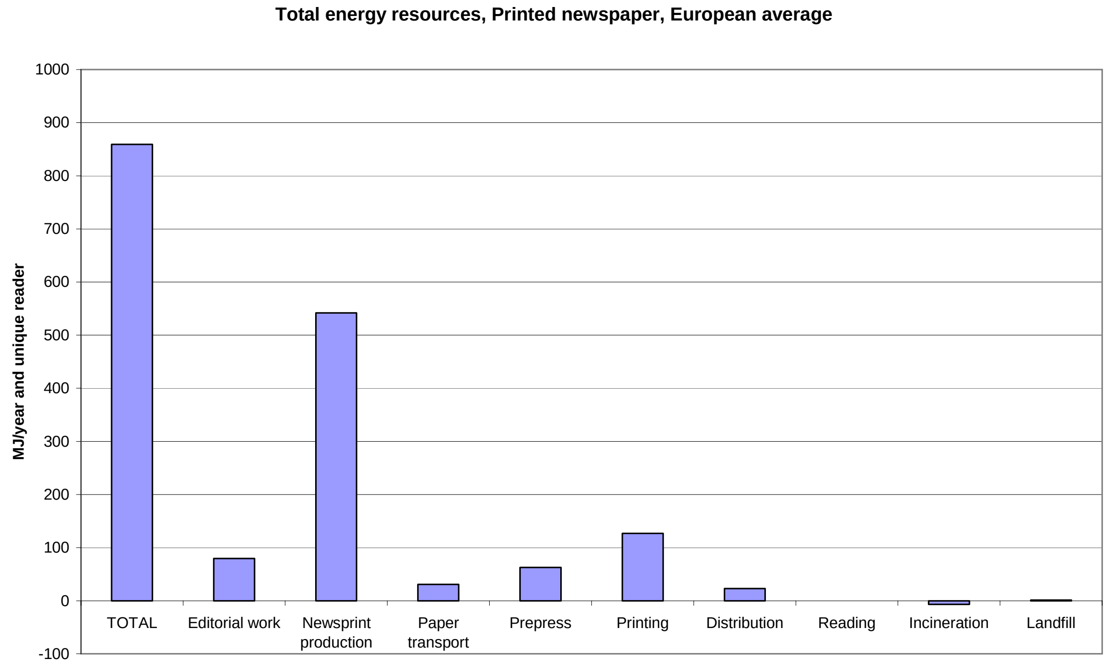


Figure 10. The total energy in the resources used for different parts of the printed newspaper life cycle in the European scenario.

Newsprint production caused more than half of the resource consumption of the product system. Of the resources used in the newsprint production 40% were from renewable sources, for the other activities the share of renewable resources was around 10%.

Main resources that contributed to the impact categories were, according to the ADP method; natural gas, hard coal and crude oil. For the abiotic exergy characterisation natural gas and uranium were the main contributors, followed by natural gas, hard coal and crude oil. For the total energy the main resources considered were biotic material, natural gas, uranium, hard coal, crude oil, hydropower and lignite, in that order.

3.2.1.2 Non-toxicological impacts

Concerning the non-toxicological impact categories (global warming, acidification, eutrophication, ozone layer depletion and photooxidant formation) the newsprint production gave rise to the largest impacts in all cases (e.g. Figure 11). Printing had the second largest values in all impact categories except the ozone depletion, where distribution and printing resulted in similar values.

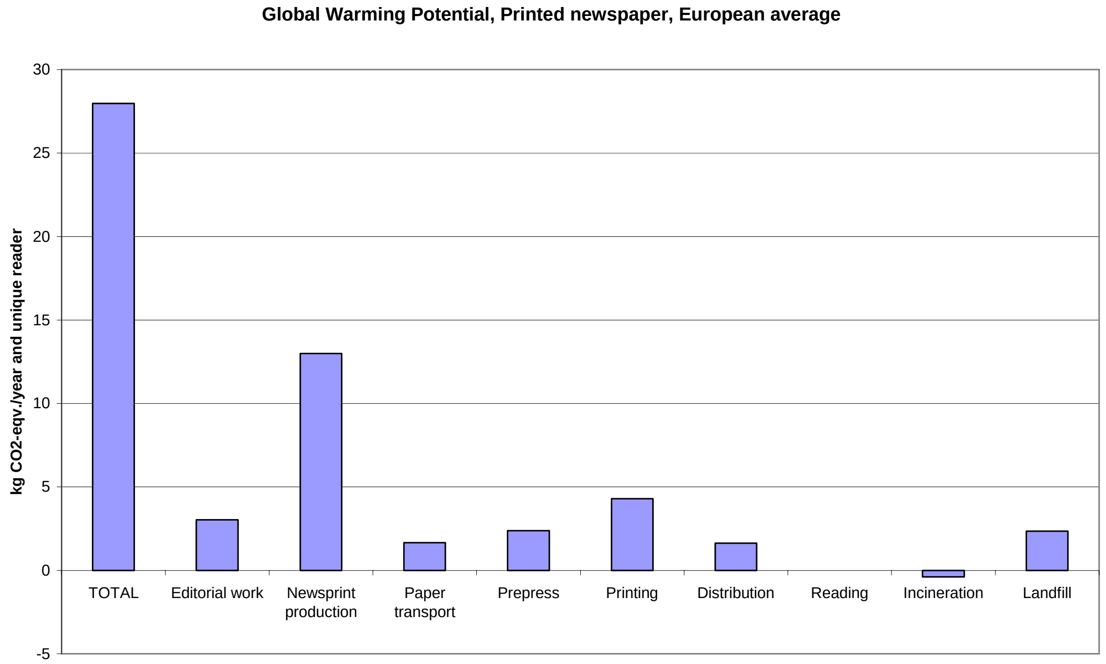


Figure 11. The global warming potential for different parts of the printed newspaper life cycle in the European scenario.

The global warming potential of the one year consumption of a printed newspaper was 28 kg CO_2-eqv./year and unique reader in the European scenario, the newsprint production caused almost half of this potential impact.

3.2.1.3 Toxicological impacts

For all four toxicological impact categories the result showed that newsprint production gave rise to the highest potential impact (e.g. Figure 12). Second was printing for terrestric ecotoxicity and human toxicity. In the freshwater and marine aquatic ecotoxicity impact categories several activities had similar values. Emissions from distribution were lacking to a great extent concerning toxicity.

Main reasons for the toxicological impacts were e.g. emissions to air and water from electricity production.

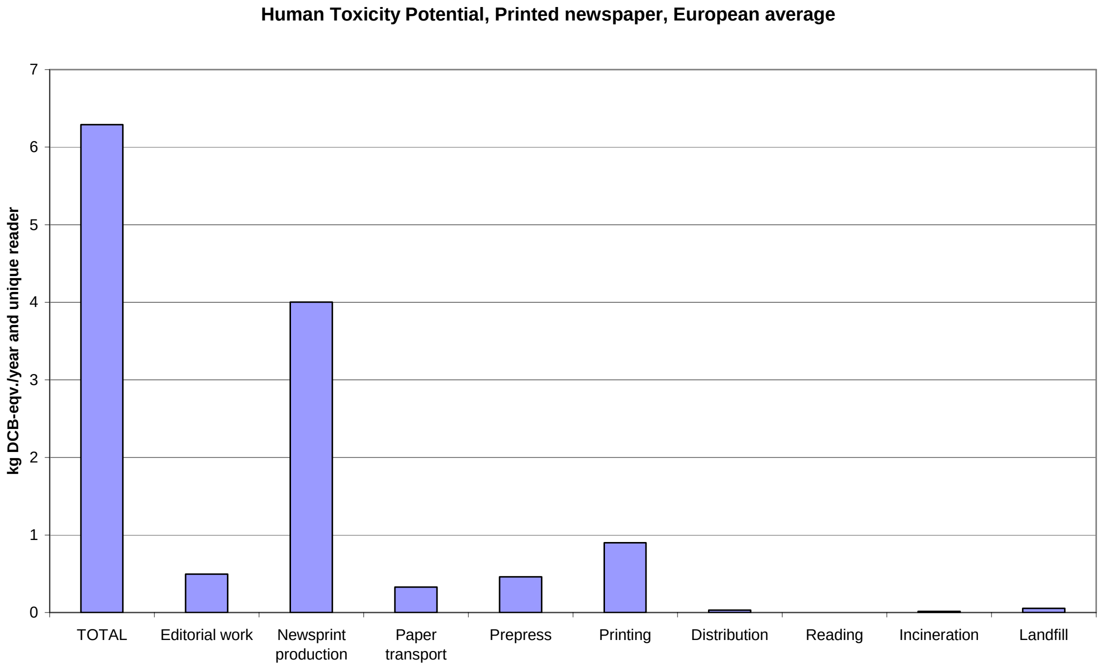


Figure 12. The human toxicity potential for different parts of the printed newspaper life cycle in the European scenario.

3.2.1.4 Weighted results

The three weighting methods showed similar but not exactly the same order of contribution to the total weighted impact for the activities part of the printed newspaper product system. Newsprint production had the largest contribution to the total weighted results; the share was 55-70%. Using the Ecotax 02 min version printing was the second largest contributor, but the difference compared to editorial work, landfill, paper transport and prepress was rather small (Figure 13). Using the Ecotax 02 max version printing, editorial work and prepress were the other main contributors (Figure 14).

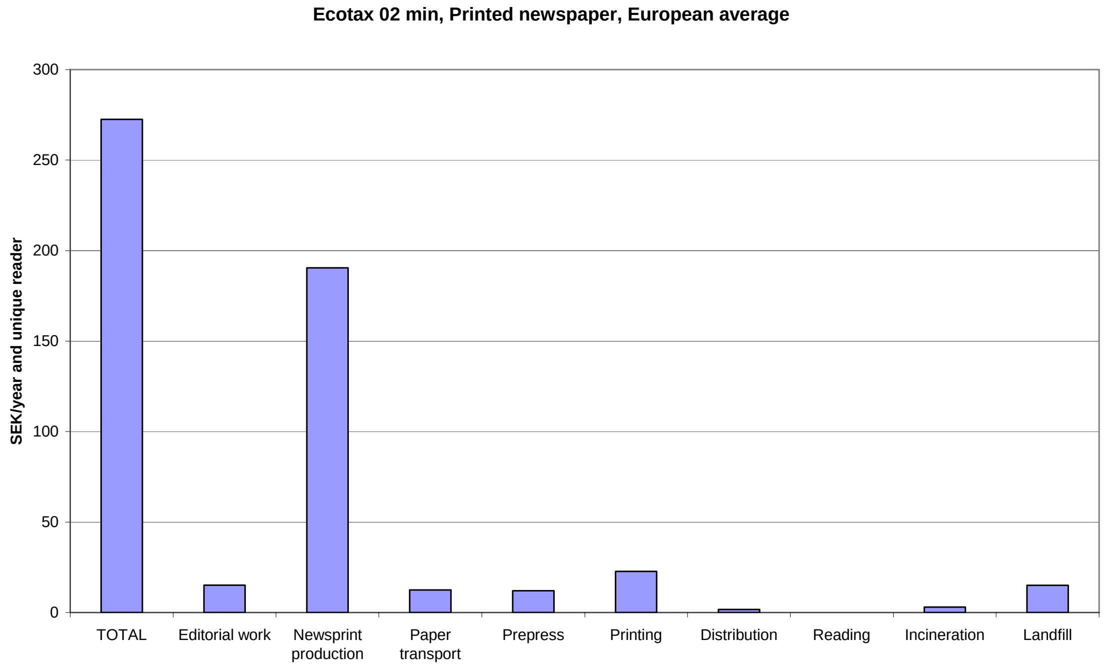


Figure 13. The total weighted values for different parts of the printed newspaper life cycle in the European scenario, using the Ecotax 02 min weighting method.

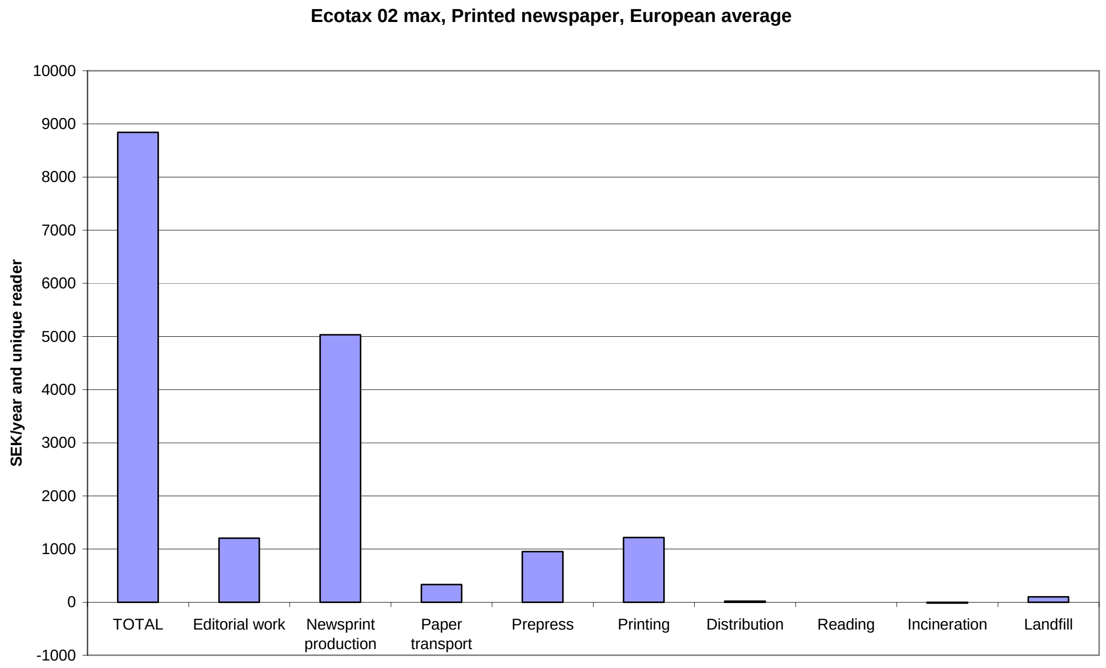


Figure 14. The total weighted values for different parts of the printed newspaper life cycle in the European scenario, using the Ecotax 02 max weighting method.

The result, when using Eco-indicator 99, showed that following newsprint production was printing, and thereafter paper transport, editorial work, distribution and prepress with similar values (Figure 15).

The total weighted value for the printed newspaper product system in the European scenario was with the Ecotax 02 min version around 270 SEK/year and unique reader, and with the Ecotax 02 max version around 8 800 SEK/year and reader. This difference in absolute values indicates the inherent uncertainties in weighting.

Emissions from electricity production were the main reasons for the total environmental impact of the printed newspaper according to the Ecotax 02 weighting method, max version. Using the min-version there were more various factors contributing to the total weighted impact.

Using the weighting method Eco-indicator 99, the resources used (natural gas and crude oil) contributed to half of the value and impacts from emissions (NO_x, SO_2, dust, CO_2, etc) the other half. In many cases these were from electricity production.

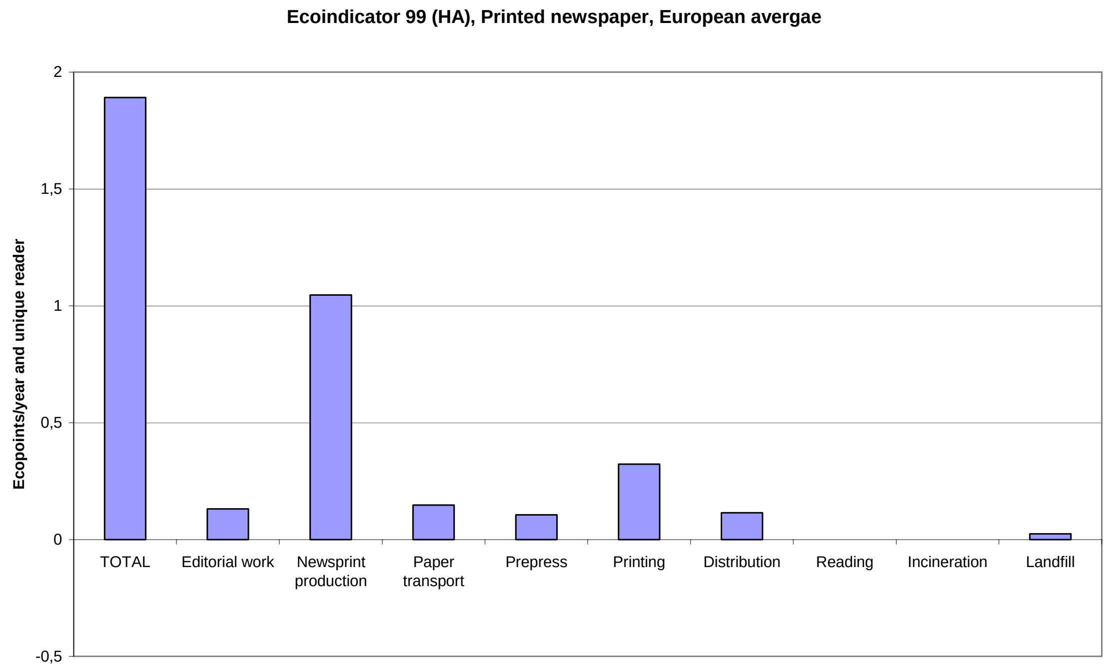


Figure 15. The total weighted values for different parts of the printed newspaper life cycle in the European scenario, using the Eoindiator 99 (HA) weighting method.

3.2.2 Swedish scenario

3.2.2.1 Resources used

The resources used for the printed newspaper in the Swedish scenario were mainly used in the newsprint production according to the impact categories abiotic depletion potential (ADP), abiotic exergy and total energy in resources (e.g. Figure 16). In the ADP category distribution was second to newsprint production followed by printing. For abiotic exergy and total energy in resources the order was the opposite; printing was second to newsprint production followed by distribution.

The distance for distribution of printed newspaper was assumed to be longer in the Swedish scenario than in the European. For the distribution only the diesel production and use was included.

The values for resources used were lower in the Swedish scenario than in the European, this is due to the electricity mix in the cases of ADP and abiotic exergy since they only cover non-renewable resources. For the total energy in resources the difference is mainly due to the fact that there is a higher degree of paper recycling in Sweden than in Europe as an average. The resources used for transport of paper were lower in the Swedish scenario since shorter distance is assumed and the mode of transport is electric freight train and truck.

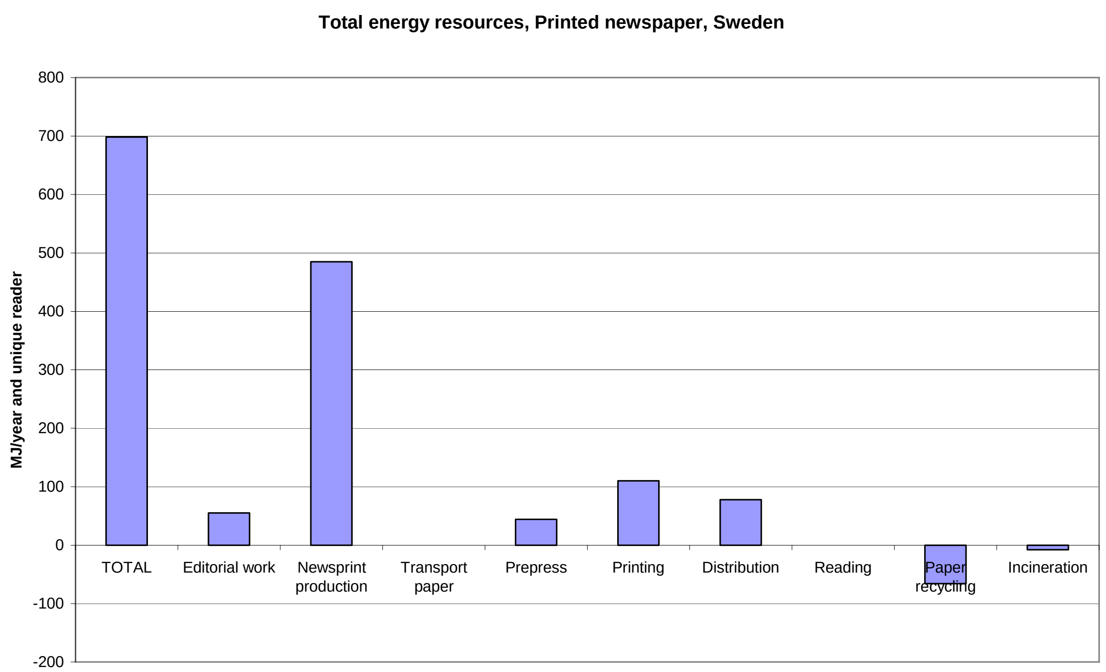


Figure 16. The total energy in the resources used for different parts of the printed newspaper life cycle in the Swedish scenario.

3.2.2.2 Non-toxicological impacts

Concerning the non-toxicological impact categories (global warming, acidification, eutrophication, ozone layer depletion and photooxidant formation) the newsprint production gave rise to the largest impacts concerning global warming, acidification and eutrophication (e.g. Figure 17). Distribution was the main source of ozone depletion and photooxidant formation. When newsprint production was the main contributor, distribution was second and the other way around.

The difference compared to the European scenario is notable. In the Swedish scenario the distribution of newspaper was contributing more to the potential non-toxicological impacts. This was due to differences in assumptions for the distribution, leading to higher diesel use in the Swedish scenario. In addition the electricity used in the two scenarios differs and the emissions from the production of the European electricity mix were contributing more to the impact categories.

The global warming potential of a one year consumption of the printed newspaper was 20 kg CO_2-eqv./year and unique reader in the Swedish scenario, about 70% of the global warming potential of the printed newspaper in the European scenario. In the Swedish scenario the newsprint production gave rise to 40% of the global warming potential and the distribution to 30%.

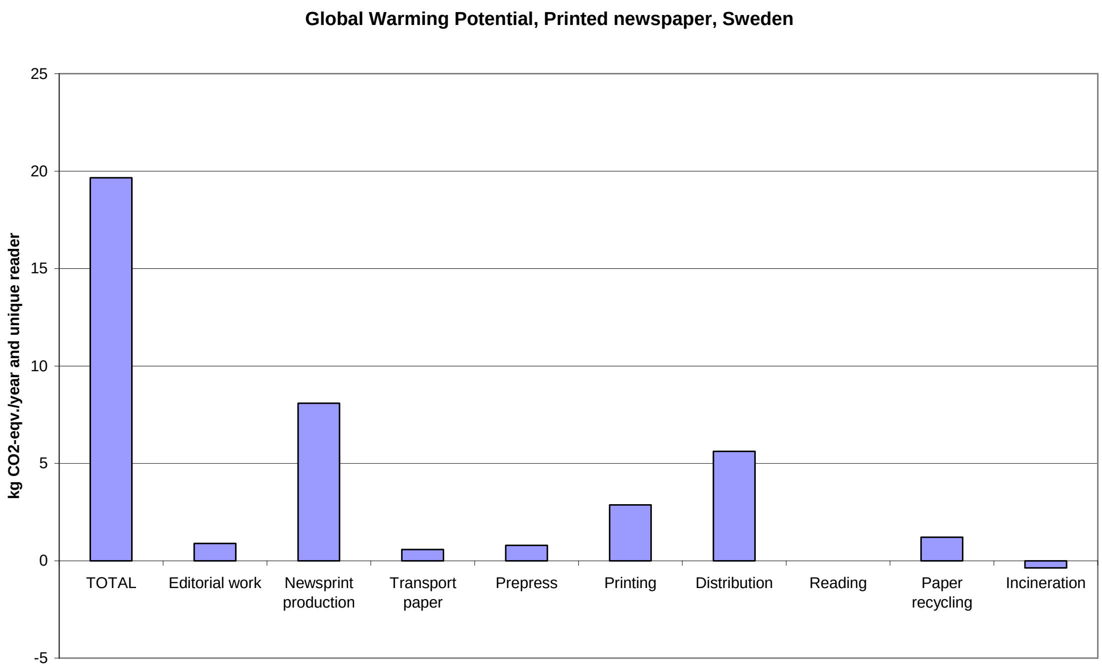


Figure 17. The global warming impact for different parts of the printed newspaper life cycle in the European scenario.

3.2.2.3 Toxicological impacts

For all four toxicological impact categories the result showed that newsprint production was giving rise to the highest impact, more than 50% of the impact for all categories (e.g. Figure 18).

The order of contribution thereafter was diverse. Second was recycling of paper, printing or prepress. Emissions from distribution were lacking to a great extent concerning toxicity.

The main reasons for the toxicological impacts were diverse, including e.g. emissions from pulp and paper production, from electricity production and from the paper recycling process.

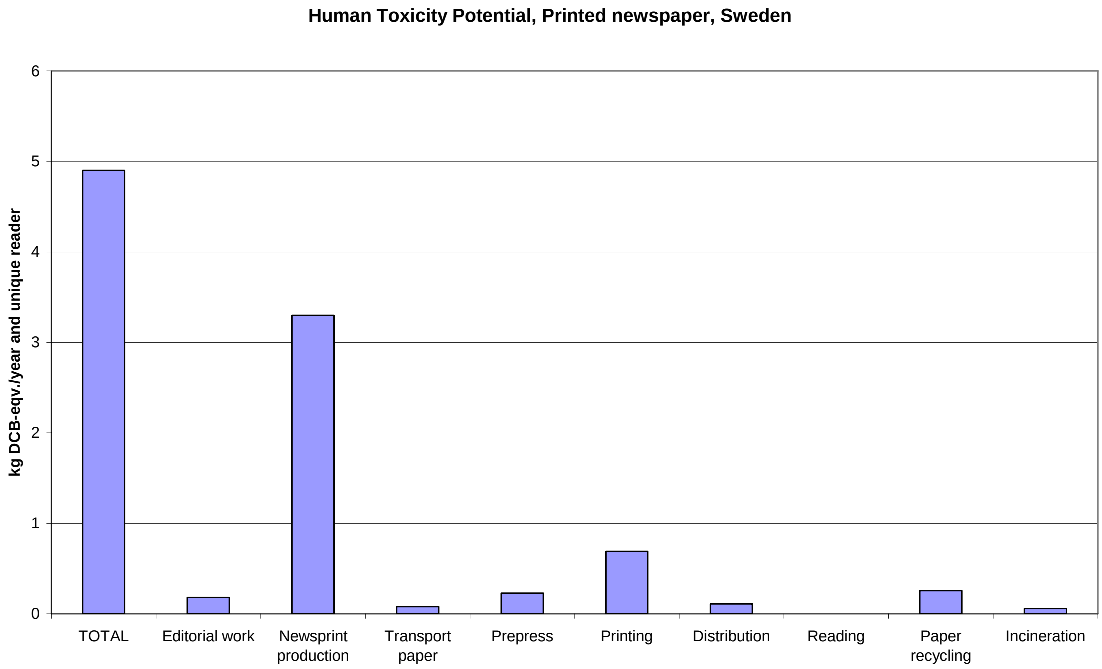


Figure 18. The human toxicity potential for different parts of the printed newspaper life cycle in the European scenario.

3.2.2.4 Weighted results

Newsprint production had the largest contribution to the total weighted results; the share was 50-70%. Using the Ecotax 02 min version, the second largest total weighted impact was caused by the recycling of paper (Figure 19). Different kinds of emissions were the reasons for the high impact values. If the max-version was used for weighting the results the second largest total weighted impact was due to printing, followed by editorial work and prepress (Figure 20). Using the Ecotax 02 max emissions caused by electricity production were higher weighted compared to the min-version.

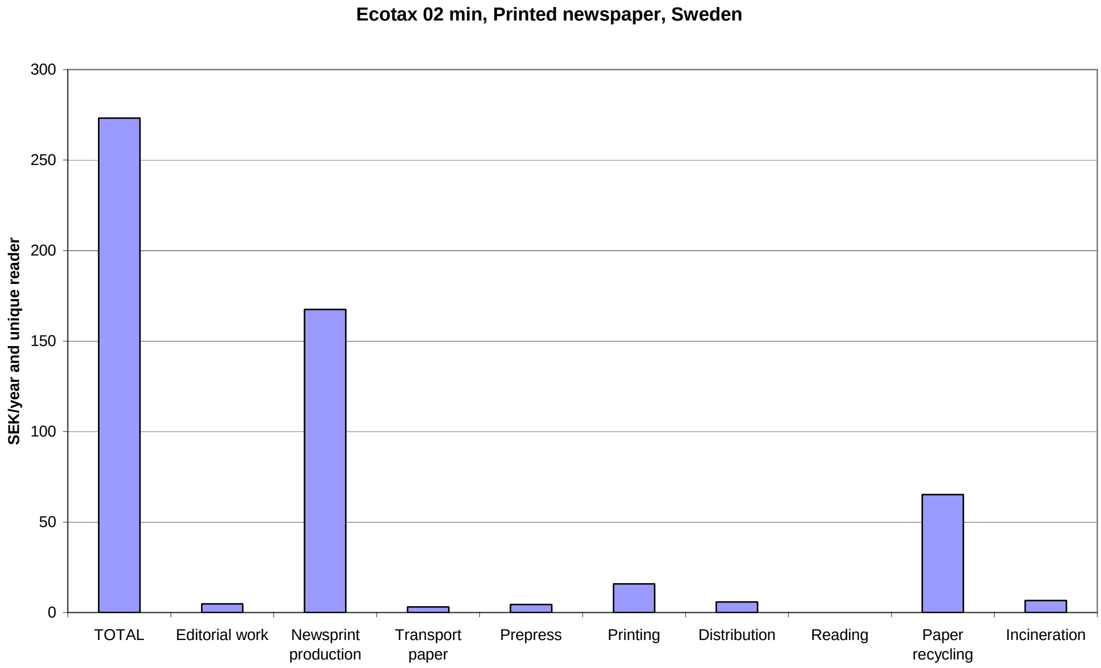


Figure 19. The total weighted values for different parts of the printed newspaper life cycle in the Swedish scenario, using the Ecotax 02 min weighting method.

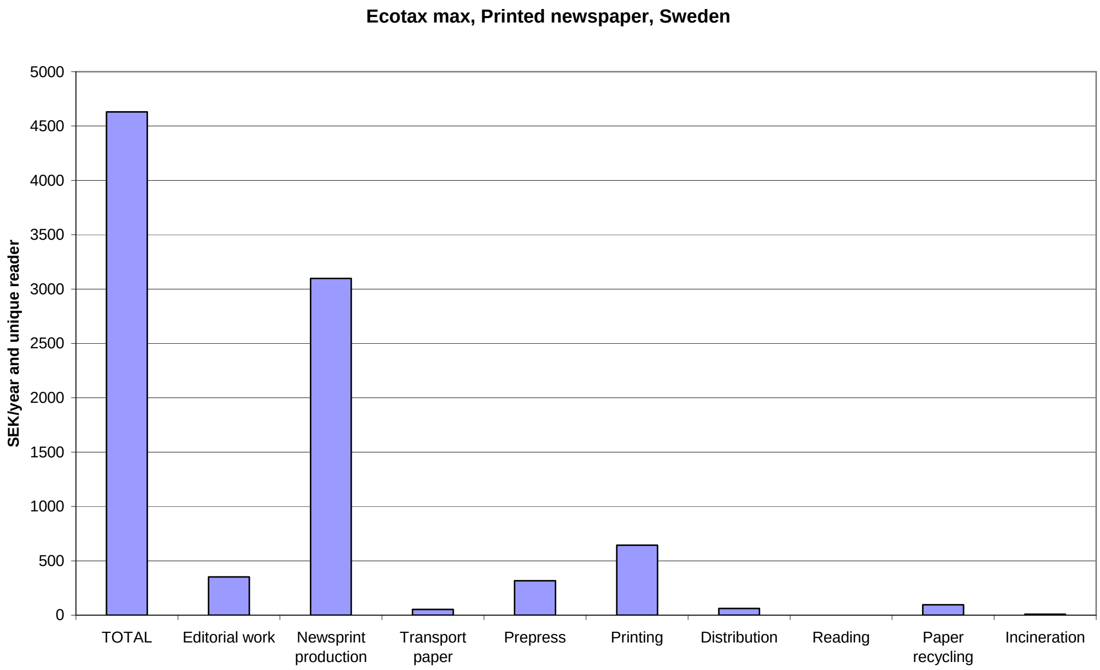


Figure 20. The total weighted values for different parts of the printed newspaper life cycle in the Swedish scenario, using the Ecotax 02 max weighting method.

The result, when using Eco-indicator 99, was that following newsprint production were distribution and printing (Figure 21). The reason that distribution was contributing more to the total weighted value when using this weighting method was that Eco-indicator, compared to Ecotax 02, gave higher weighting to resource use and less to toxicological impacts. For distribution toxic emissions were to a great extent missing.

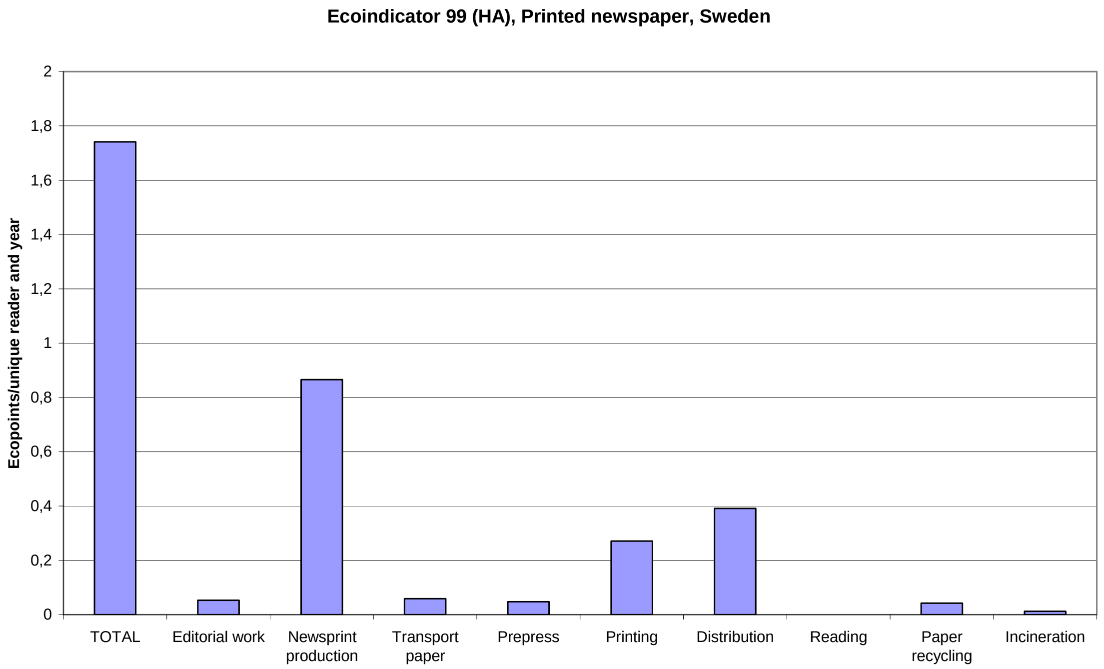


Figure 21. The total weighted values for different parts of the printed newspaper life cycle in the Swedish scenario, using the Ecoindicator 99 (HA) weighting method.

The total weighted value for the printed newspaper product system in the Swedish scenario was with the Ecotax 02 min version around 270 SEK/year and unique reader, and with the Ecotax 02 max version around 4 600 SEK/year and reader. The lower value was the same as in the European scenario, but the higher value was almost half of the value in the European scenario.

Emissions from electricity production were the main reasons for the total environmental impact of the printed newspaper according to the Ecotax 02 weighting method, max version. Using the min-version emissions contributing to the toxicological impacts from newsprint production, paper recycling etc. contributed the most to the total value.

Using the weighting method Eco-indicator 99, non-renewable energy resources contributed to more than half of the total value and impacts from emissions (NO_x, CO_2, dust, SO_2, etc) the other part.

3.3 Web based newspaper

3.3.1 European scenario

3.3.1.1 Resources used

Calculating the abiotic depletion potential (ADP) the energy for reading made out the largest part of the total value, second was editorial work and thereafter PC production and screen production. The resources that made out the main part of the total value were hard coal, natural gas, lignite and crude oil. The pattern was the same for total energy (Figure 22) and abiotic exergy. For the total energy category and the abiotic exergy the main contribution were from uranium, hard coal and natural gas. It should be noted that the PC and screen material recycling was not included in the study; this would decrease the virgin resource use for these. However, the metals and other resources not used for energy generation seemed to have little part in the overall assessment of resources used.

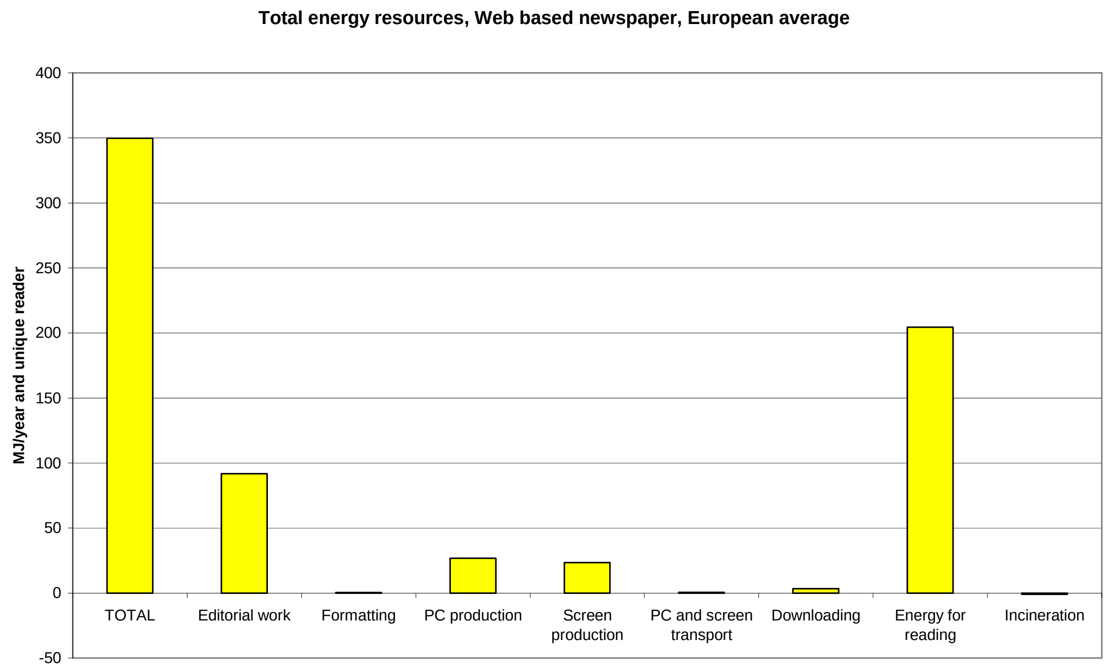


Figure 22. The total energy in the resources used for different parts of the web based newspaper life cycle in the European scenario.

The total energy in resources used was for one year consumption of a web based newspaper 350 MJ.

3.3.1.2 Non-toxicological impacts

Concerning the non-toxicological impact categories the energy use for reading was the main contributor in all impact categories; acidification, eutrophication, photooxidant formation, ozone depletion and global warming. For acidification, eutrophication and photooxidant formation editorial work and screen production were second. The second largest contribution to the ozone depletion category was PC production.

Regarding the global warming potential the energy used for reading on the screen was the main contributor, followed by the editorial work. PC and screen production also made out part of this impact potential. The total global warming potential for a one year consumption of a web based newspaper were 14 kg CO_2/year and reader, out of which the energy for reading caused 8 kg CO_2/year (Figure 23).

The emissions contributing to the non-toxicological impact categories in the web based newspaper product system are mainly from electricity production.

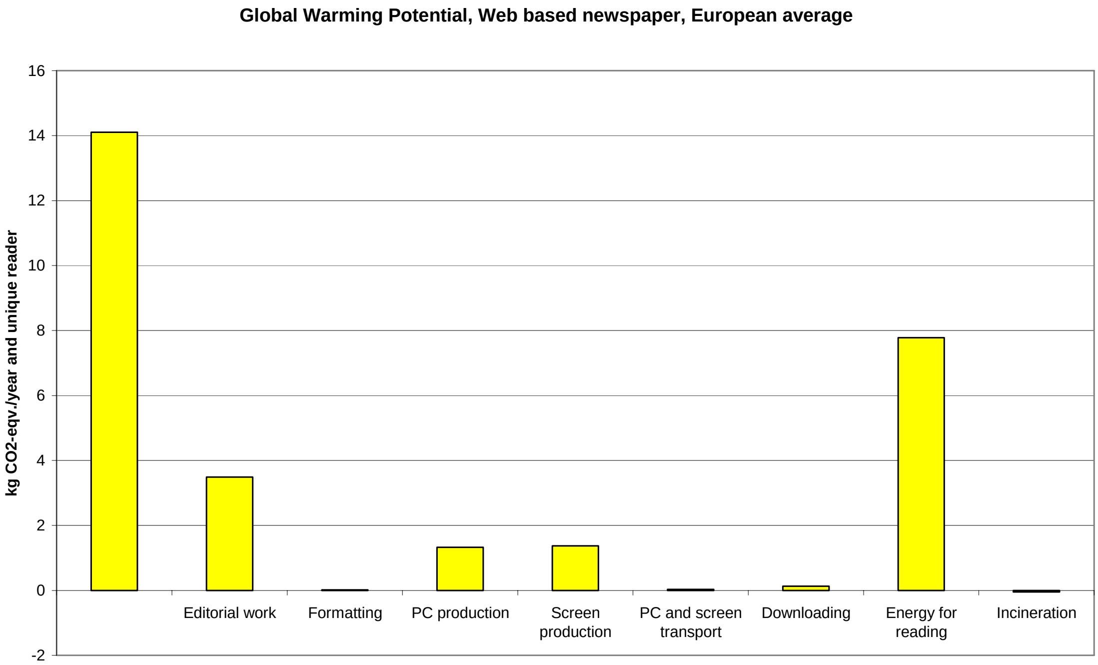


Figure 23. Global warming potential for the Web based newspaper in the European scenario.

Toxicological impacts

For the toxicological impacts the reading of the web based newspaper was the main contributor to all four categories. The incineration of plastic parts of waste electronics was second in the freshwater aquatic ecotoxicity and the human toxicity (Figure 24) cases. The material recycling of 70% of the waste PC and screen was not included in the study due to lack of LCI data. The inclusion of material recycling could both mean increased and decreased impacts depending on the emissions from the material recycling processes as compared to emissions from virgin production.

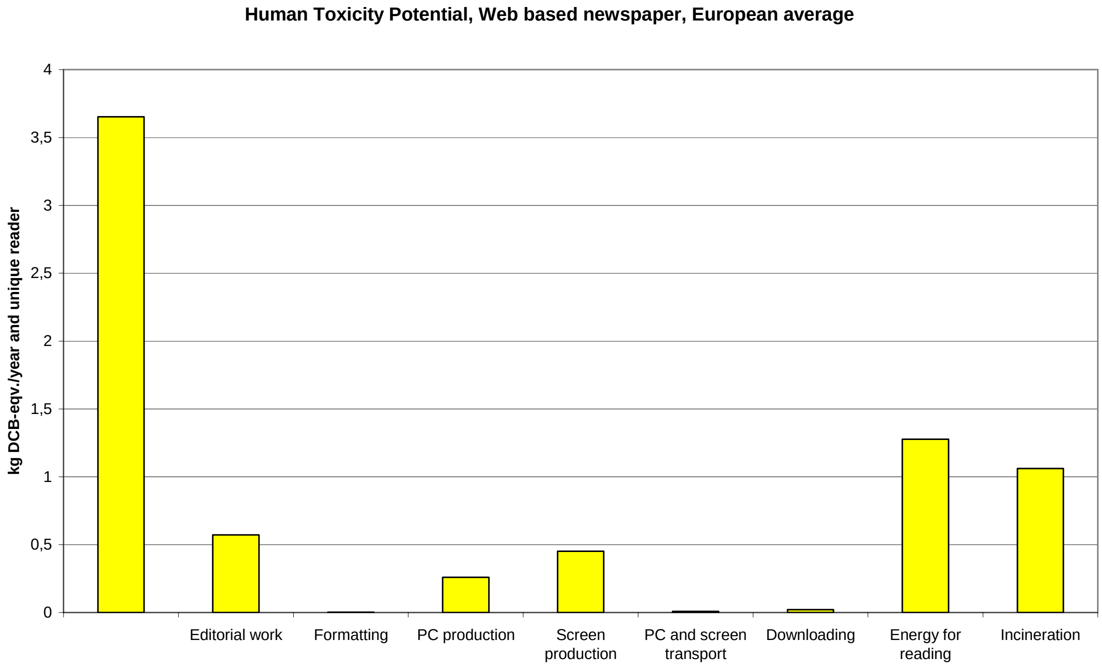


Figure 24. The potential human toxicity impact of the different activities part of the web based newspaper's life cycle.

Editorial work was second largest contributor in the marine aquatic (together with screen production) and the terrestric toxicity impact categories.

3.3.1.3 Weighted results

The three different weightings show similar results. Using the Ecotax 02 min version the main contributor was the energy for reading, followed by editorial work and incineration of waste electronics (Figure 25). Using the Ecotax 02 max version energy for reading was followed by editorial work and screen production (Figure 26). The Ecoindicator 99 weighting results in the same two main contributing activities; energy for reading followed by editorial work (Figure 27). PC and screen production are third, with similar values.

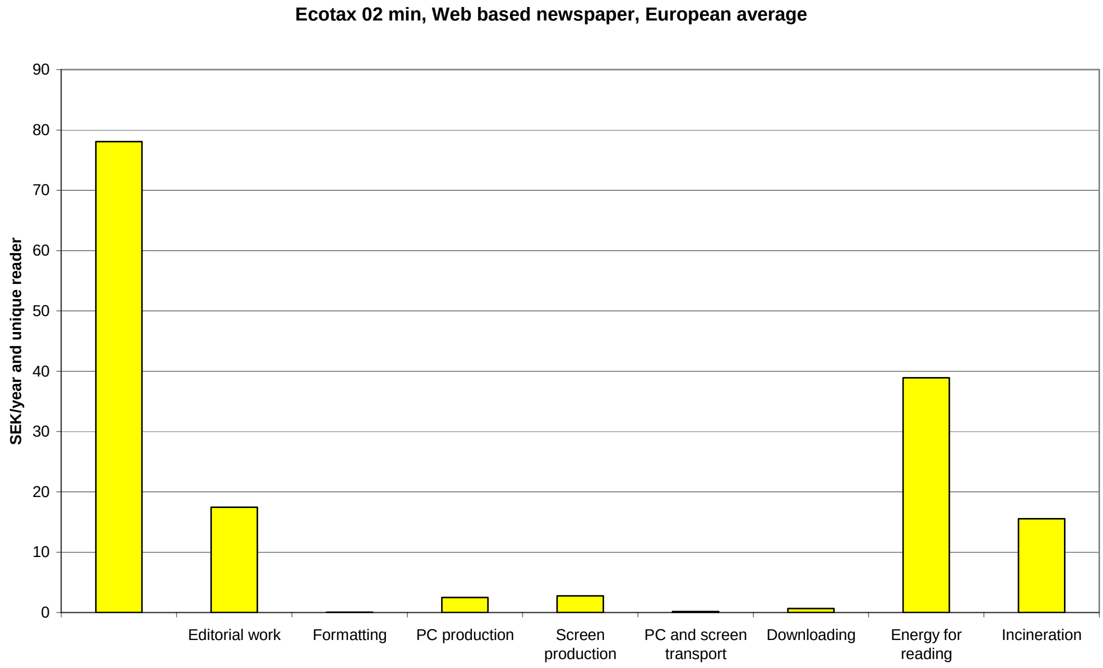


Figure 25. Weighted results of the screening LCA of Web based newspaper in the European scenario, using the weighting method Ecotax 02, min version.

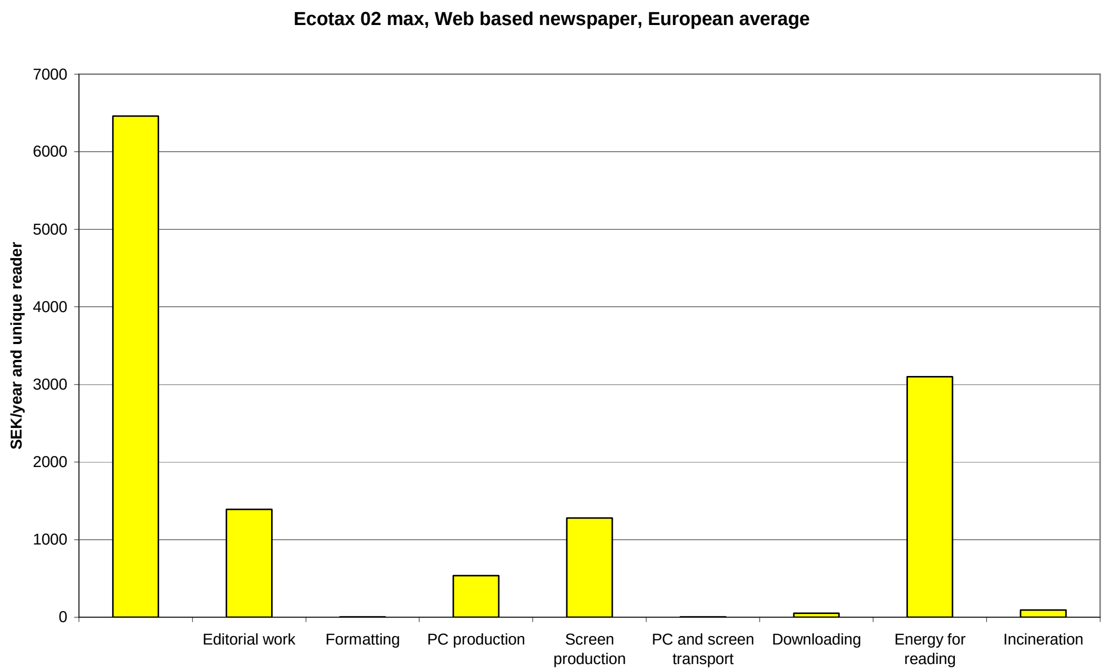


Figure 26. Weighted results of the screening LCA of Web based newspaper in the European scenario, using the weighting method Ecotax 02, max version.

The difference between the two Ecotax versions, min and max, is from 80 SEK to 6 500 SEK per year and unique reader. This illustrates the inherent uncertainties in weighting. However, even though the difference in absolute values was large, all three weightings result in the same two activities contributing the most to the potential environmental impact; energy for reading and editorial work. Both these activities were here equivalent to use of electricity. In addition, PC and screen production as well as incineration of waste electronics (plastics) were main parts of the total weightings, differing between the methods.

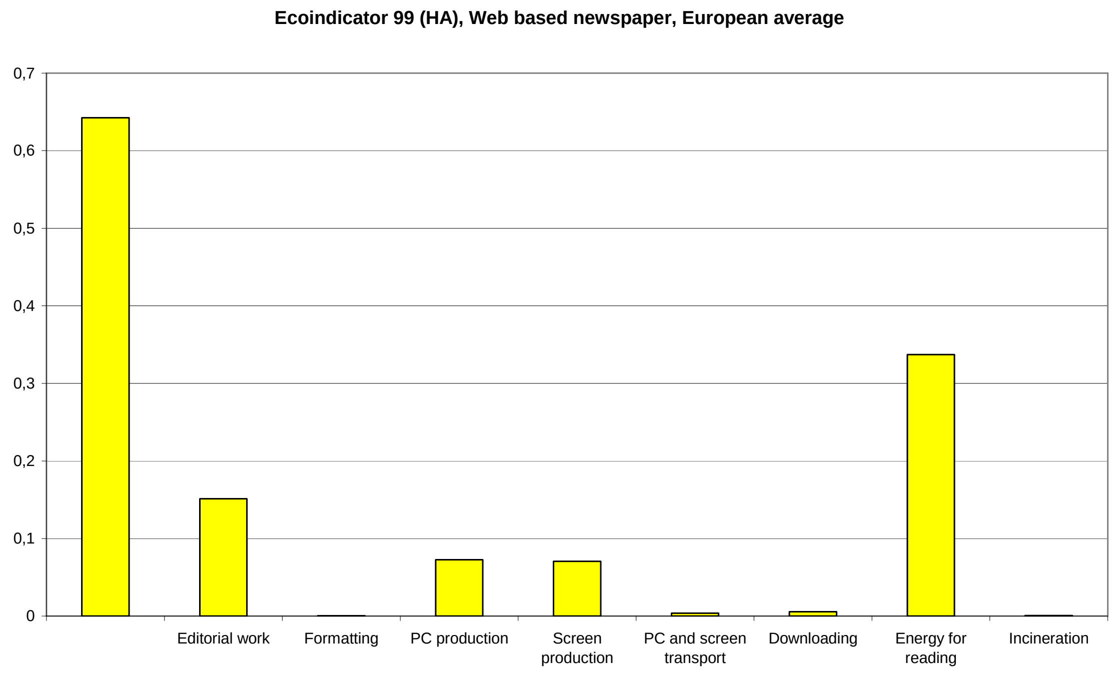


Figure 27. Weighted results of the screening LCA of Web based newspaper in the European scenario, using the weighting method Ecoindicator 99, Hierarchist approach.

3.3.2 Swedish scenario

3.3.2.1 Resources used

Using the ADP or the abiotic exergy method, the energy for reading made out 40% or more of the total resource use. Production of screen and PC and editorial work contributed with about 20% each of the total potential impact. The main parts of the total value were hard coal, natural gas and crude oil.

The pattern for total energy in resources used (covering non-renewable and renewable resources) was similar but not the same, with energy for reading as the major part (55%) followed by editorial work (25%) and then PC and screen production (Figure 28). For the total energy category the main contributions were primary energy from hydropower, uranium, hard coal and natural gas. It should be noted that the PC and screen material recycling was not included in the study. Including this would have decreased the virgin resource use. However, the metals and other resources not used for energy generation seem to be of minor importance in the overall assessment of resources used. Thus the effect of including the material recycling will depend on the energy use for virgin production and recycling respectively.

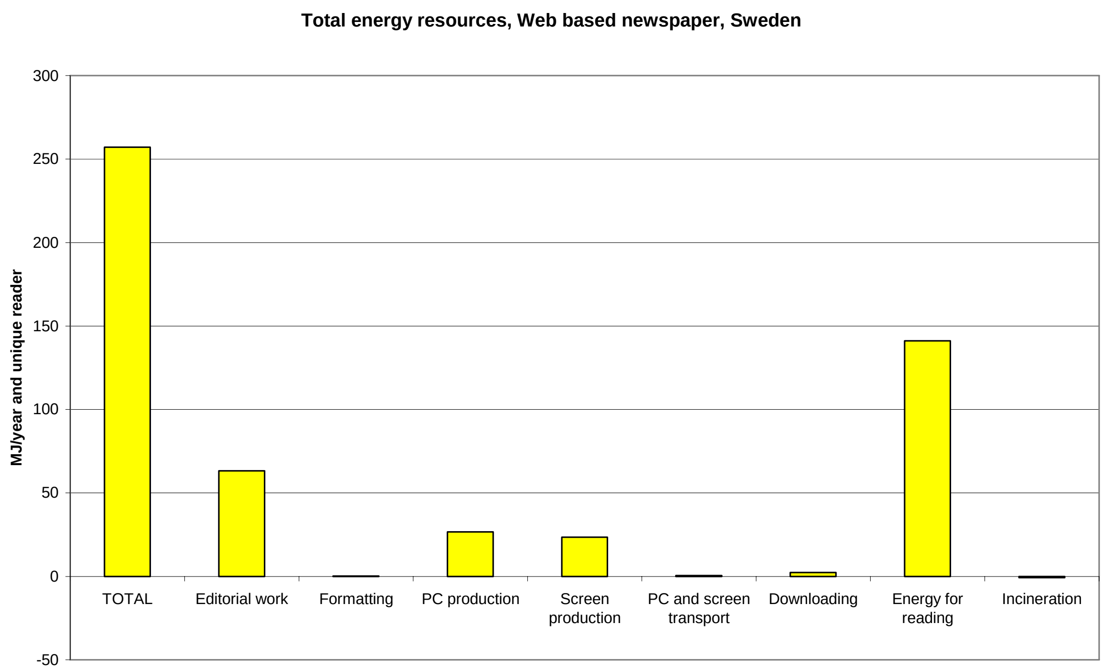


Figure 28. The total energy in the resources used for different parts of the web based newspaper life cycle in the European scenario.

3.3.2.2 Non-toxicological impacts

In the Swedish scenario the TFT screen production and the PC production together made out about 70% of the acidification and photooxidant formation categories. Screen production was the major contributor to the eutrophication category, followed by energy for reading. Regarding the ozone depletion potential, the PC production was the reason for 45% of the total impact. This difference compared to the pattern in the European scenario was due to the different electricity mixes used. The Nordel electricity mix gave rise to less emission of e.g. sulphur dioxide and nitrogen oxides than the UCTE electricity mix.

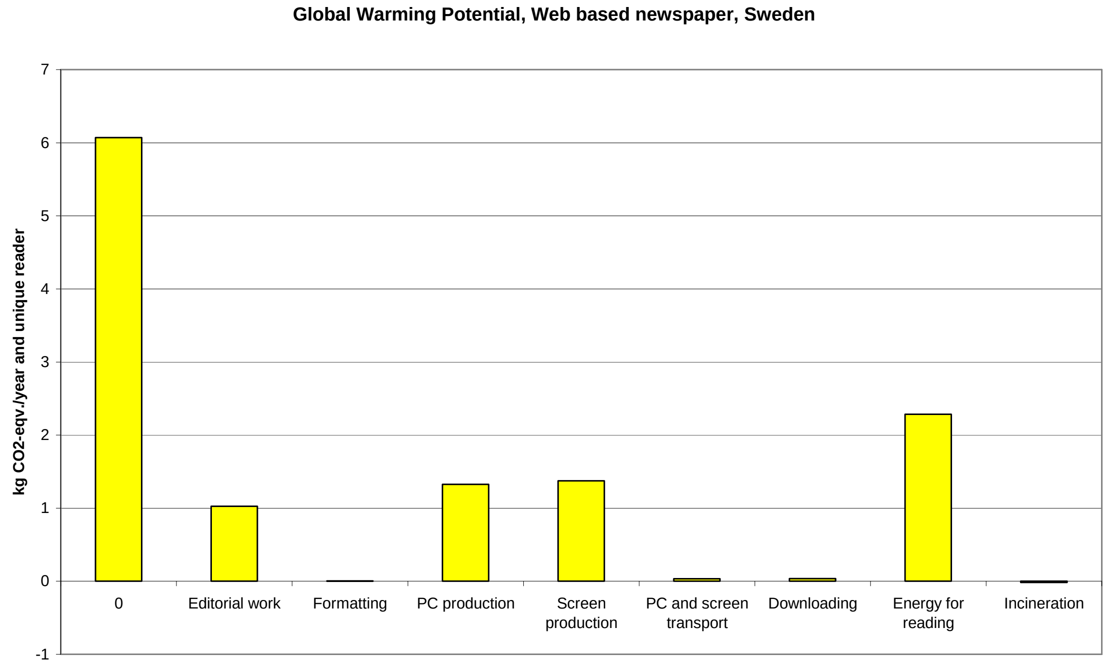


Figure 29. Global warming potential for the Web based newspaper in the Swedish scenario.

Energy for reading was the main contributor to the total global warming potential of the web based newspaper product system in the Swedish scenario (Figure 29).The total potential emissions for a one year consumption of the web based newspaper in Sweden were 6 kg CO_2/year and reader, which was less than half of the amount compared to the European scenario. This difference was also caused by the differences in electricity mixes.

3.3.2.3 Toxicological impacts

Concerning the toxicological impacts the incineration of plastic parts of waste electronics were the main contributor in the freshwater aquatic ecotoxicity (65%) and the human toxicity (40%) cases (Figure 30).

The energy use for reading and editorial work together made out 60 % and 25 % respectively of the category terrestric toxicity. Screen production was the main contributor to the marine aquatic toxicity potential of the studied web based product system.

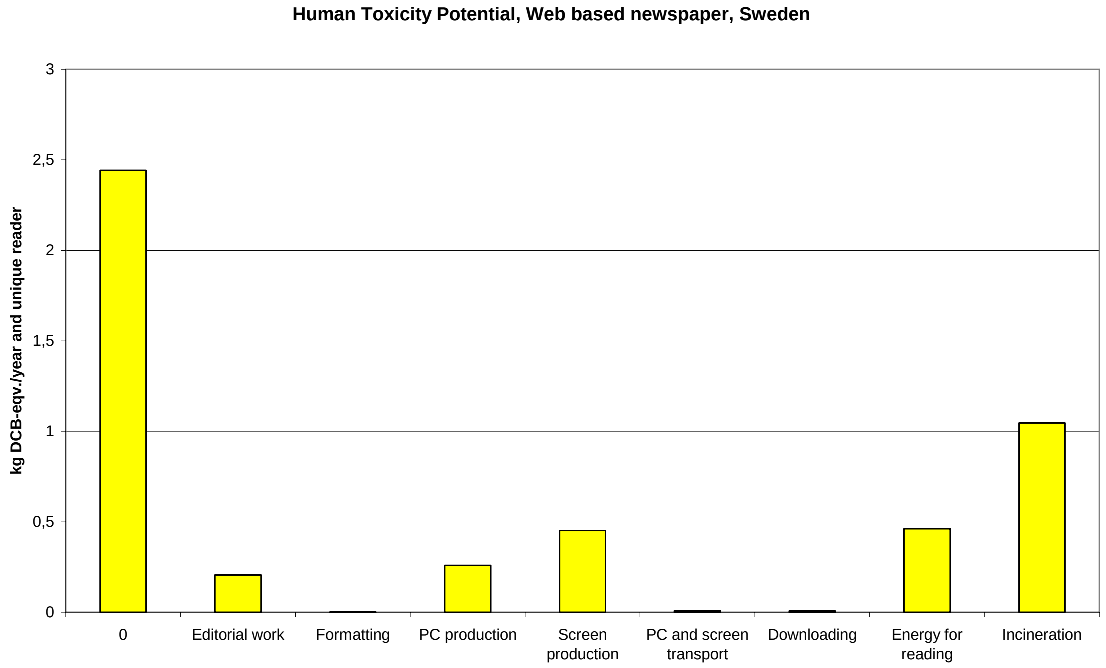


Figure 30. The potential human toxicity impact of the different activities part of the web based newspaper's life cycle.

3.3.2.4 Weighted results

The three different weightings show different results. Using the Ecotax 02 min version the main contributor was the incineration of plastics parts of the waste PC and screen, followed by energy used for reading (Figure 31). Using the Ecotax 02 max version the screen production stood for the largest part of the total weighted value, followed by energy for reading and PC production (Figure 32). The Ecoindicator 99 gave a weighted result where energy for reading stood for 40% of the total weighted value and screen production, PC production and editorial work for roughly 20% each (Figure 33).

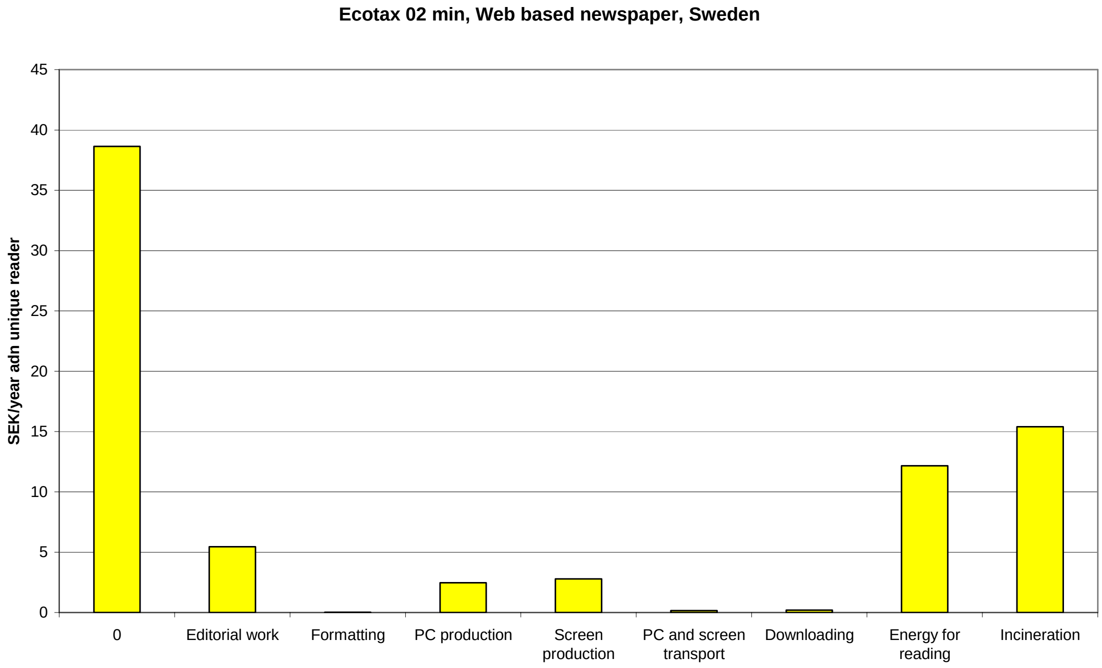


Figure 31. Weighted results of the screening LCA of Web based newspaper in the Swedish scenario, using the weighting method Ecotax 02, min version.

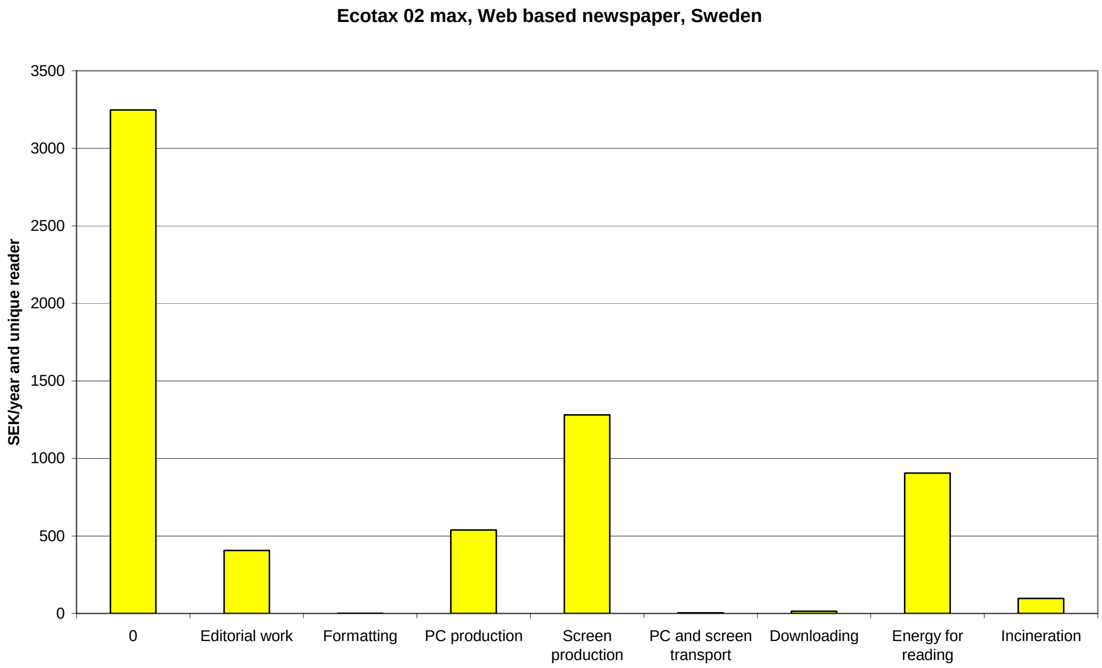


Figure 32. Weighted results of the screening LCA of Web based newspaper in the Swedish scenario, using the weighting method Ecotax 02, max version.

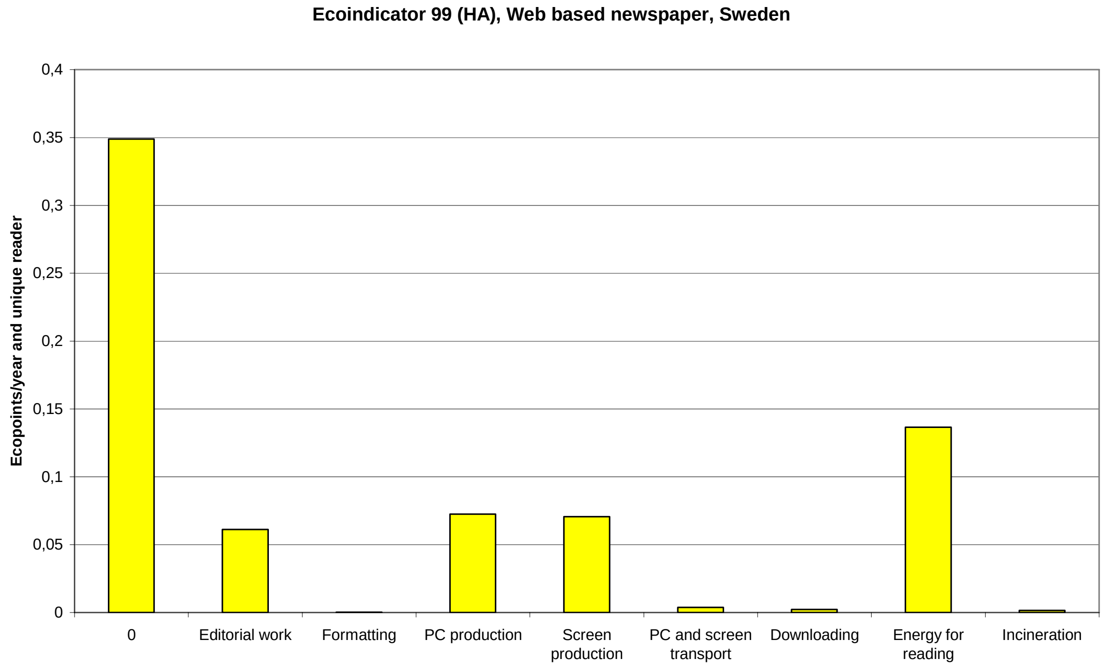


Figure 33. Weighted results of the screening LCA of Web based newspaper in the Swedish scenario, using the weighting method Ecoindicator 99, Hierarchist approach.

3.3.3 Web based newspaper European scenario, including print-out

As there is a possibility that the web based newspaper is not only read on screen; part of the web based newspaper may be printed on a home printer, a scenario where 2 A4-pages were assumed to be printed each day by each unique reader was also studied.

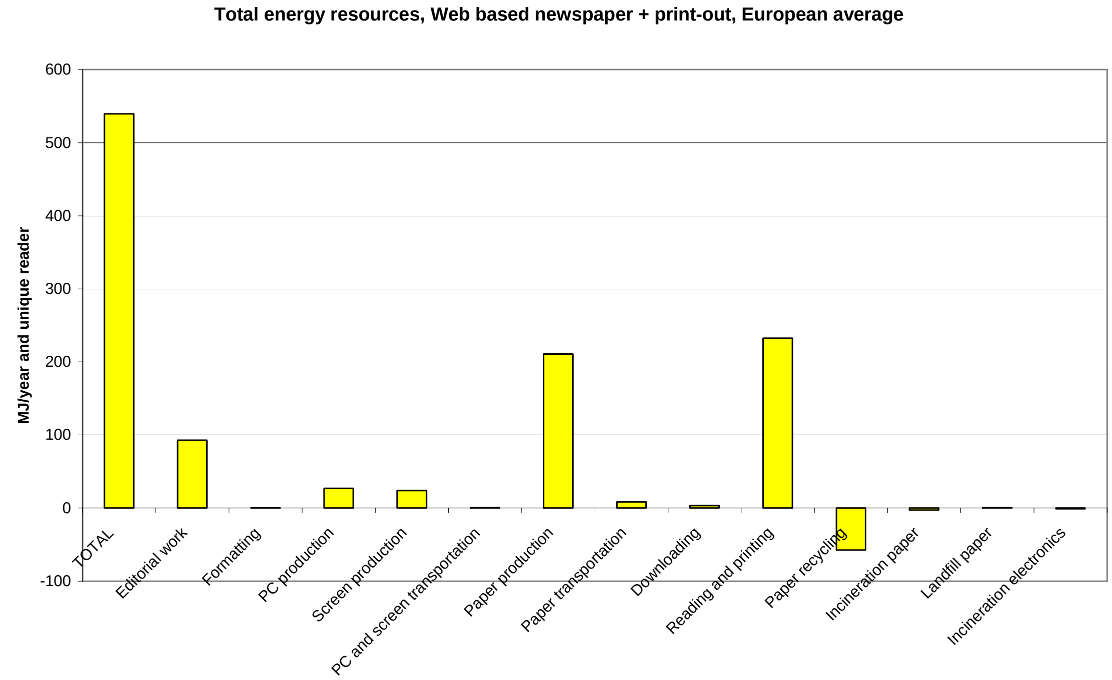


Figure 34. The total energy in the resources used for different parts of the web based newspaper life cycle in the European scenario, when printing out 2 A4-pages per day and unique reader.

Results from this scenario showed that printing made a difference for total energy in the resources used, which was 540 MJ/year and unique reader in this scenario (Figure 34). This can be compared to the European scenario without printing where the total energy in resources used was 350 MJ/year and unique reader. Paper production made out 40% of the total. The energy used for reading on screen and printing was another 40% of the total potential impact. The increase was largest concerning the total energy in resources used, since the biotic resources are included. Thus the paper production was not as significant in the abiotic depletion (ADP) and abiotic exergy impact categories.

The difference compared to the web based newspaper which was not printed is illustrated in Figure 35.

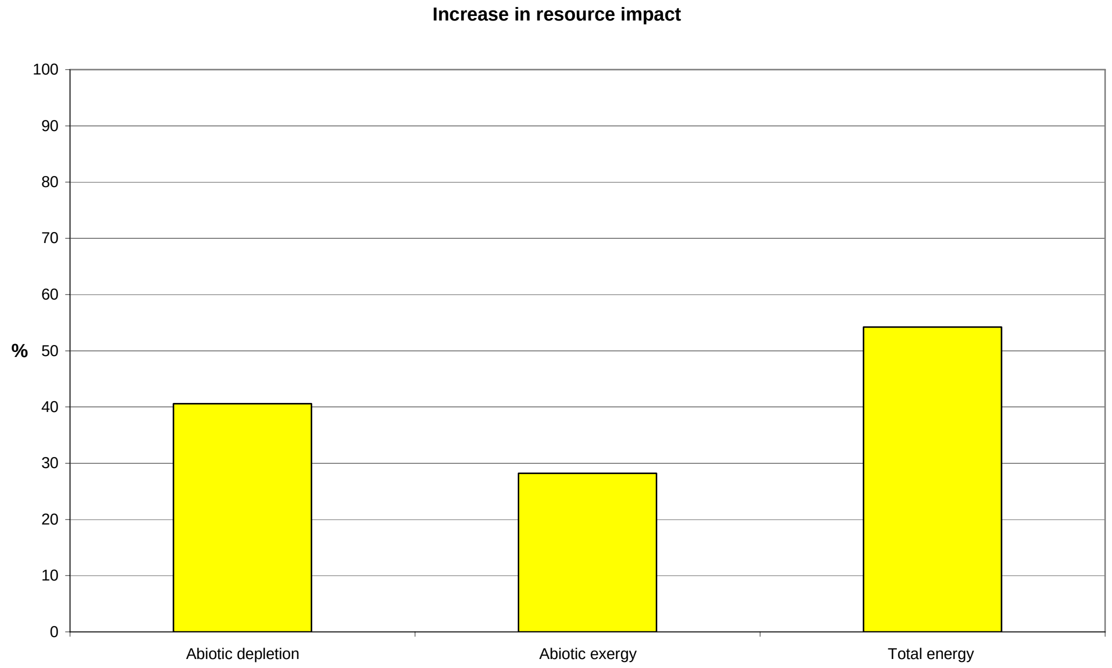


Figure 35. The increase in potential resource impact for the web based newspaper, European scenario, when the print-out of 2 A4-pages/day and unique reader was added. It should be noted that the scale is 0-100% increase, which is not the case in Figure 37 and Figure 38.

The paper production was contributing significantly to the non-toxicological as well as the toxicological impact categories. Paper production made out 10% of the global warming potential of the studied system (Figure 36).

Comparing the total value for global warming potential, 19 kg CO_2-eqv/year and unique reader, with the value for the web based newspaper only read on the screen, 14 kg CO_2-eqv/year, there is a 35% increase of global warming potential (Figure 37). This can also be compared to the global warming potential of 28 kg CO_2-eqv/year and unique reader for the printed newspaper in the European scenario. It can be noted that the energy for reading and printing gave rise to roughly 40% and the editorial work to about 20% of the total global warming potential in the scenario where print out of web based newspaper was assumed.

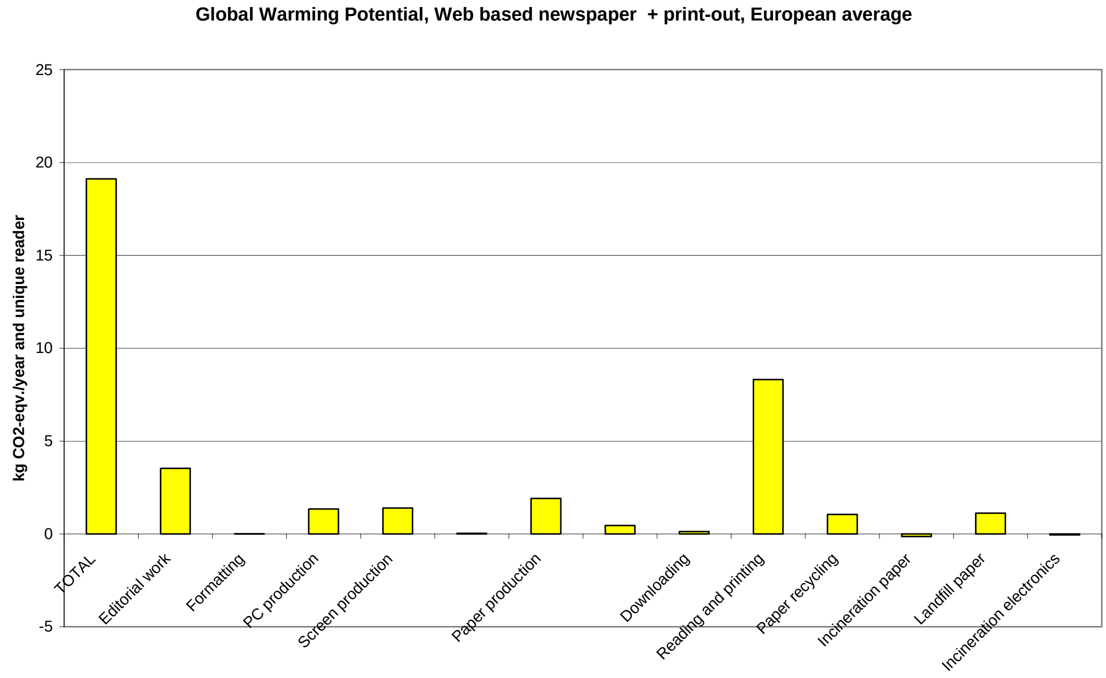


Figure 36. Global warming potential for the Web based newspaper, European scenario with print-out.

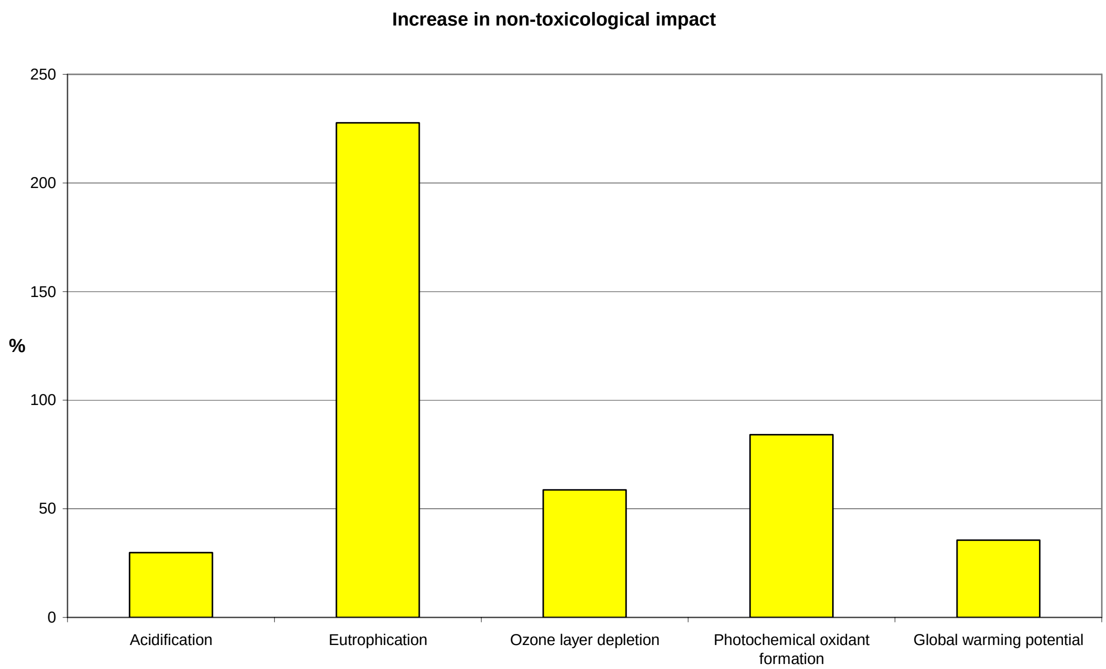


Figure 37. The increase in potential non-toxicological impact for the web based newspaper, European scenario, when the print-out of 2 A4-pages/day and unique reader was added. It should be noted that the scale is 0-250% increase.

The increase of potential non-toxicological impact, as compared to the scenario without print-out, varies from 30% to 230% (Figure 37). In the case of eutrophication, the potential impact of paper production only was on its own larger than the total potential impact of the studied product system without printing.

Regarding the total weighted values the main increase could be seen in the Ecotax min weighted values (Figure 38). Emissions from paper production and paper recycling were the main reasons for this increase. The total weighted values for the web based newspaper with print-out of 2 A4-pages per day were 65-85% of the total weighted value for the printed newspaper in the European scenario.

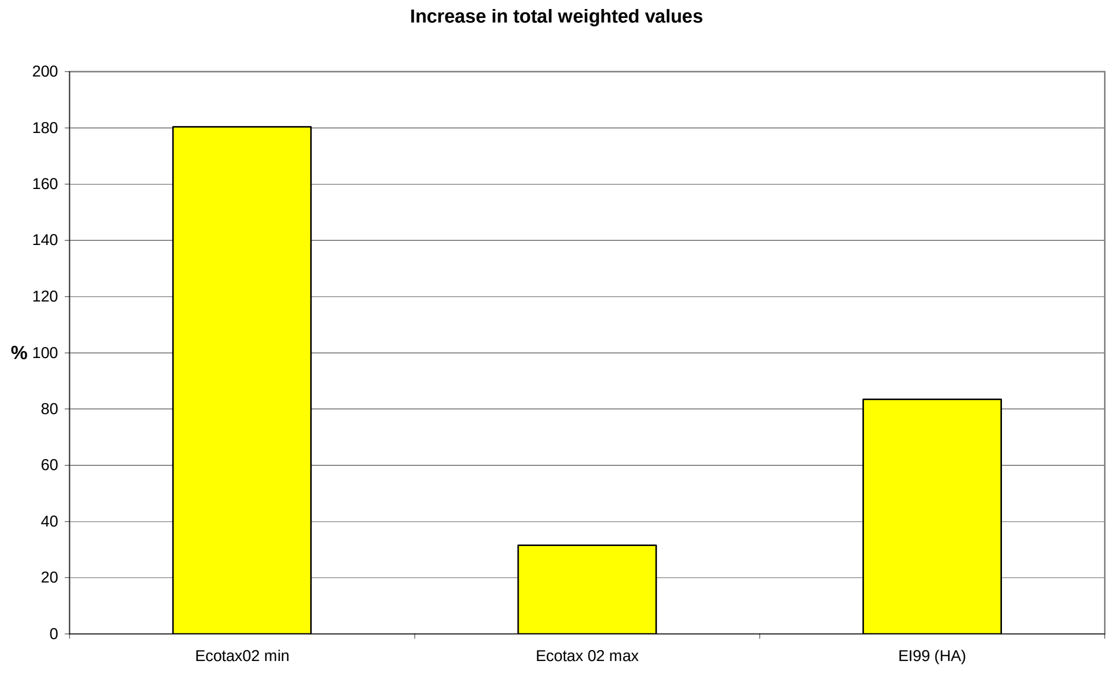


Figure 38. The increase in potential total weighted impact for the web based newspaper, European scenario, when the print-out of 2 A4-pages/day and unique reader was added. It should be noted that the scale is 0-200% increase.

3.3.4 Web based newspaper European scenario, including infrastructure

In one scenario the infrastructure for electronic distribution was included. However, due to lack of data old input-output data for USA were used. These data were not relevant since much has happened in the ICT sector since 1998. As no other data were available these data were used to get a rough estimation, illustrating whether the infrastructure may be important to consider in future studies. The results from the assessment of the web based newspaper product system, including the infrastructure data, were that the impact from infrastructure was significant. However, the conclusions to be drawn were rather that this would be interesting to study more with newer and more precise data.

3.4 Tablet e-paper newspaper

3.4.1 European scenario

3.4.1.1 Resources used

Studying the tablet e-paper newspaper in the European scenario, the main activity concerning resources used was the production of the e-paper device which made out 70% of the total value. The other activity that contributed to the resource use was the editorial work, 30% (Figure 39). This result was the same, studying the abiotic depletion potential (ADP), the total energy in resources used or the abiotic exergy.

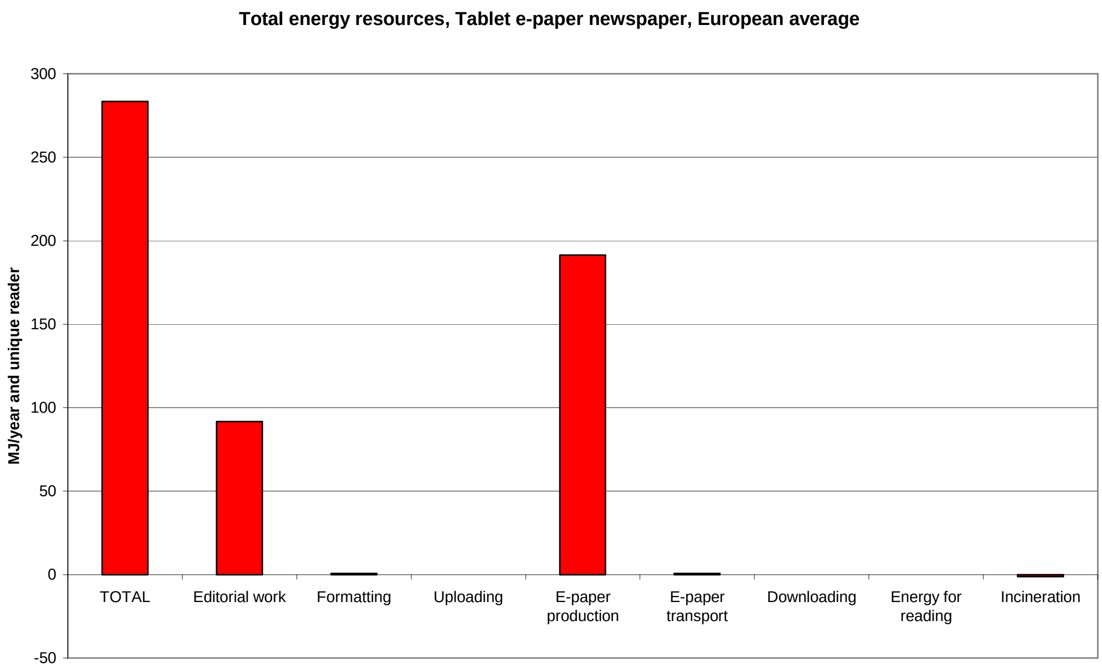


Figure 39. The total energy in the resources used for different parts of the tablet e-paper newspaper life cycle in the European scenario.

The resources natural gas and hard coal were the main part of the ADP value. Regarding the total energy in resources and the abiotic exergy uranium, natural gas and hard coal made out the major part of the result.

3.4.1.2 Non-toxicological impacts

For the non-toxicological impact categories (acidification, eutrophication, ozone layer depletion, photooxidant formation and global warming) the production of the tablet e-paper device made out the largest part of the impact and the other activity contributing to these impact categories was the editorial work (e.g. Figure 40). The tablet e-paper newspaper product system studied gave rise to almost 13 kg CO_2-eqv. /year and unique reader, which can be compared to 14 kg CO_2-eqv. /year and unique reader for the web based newspaper in the European scenario.

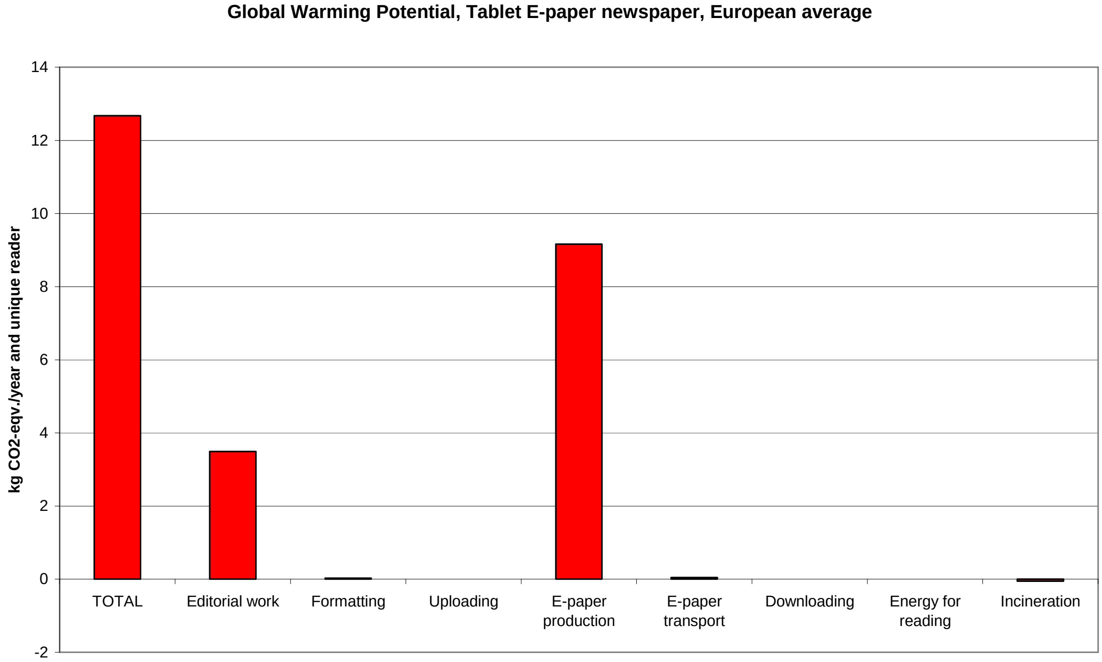


Figure 40. The potential global warming impact for different parts of the tablet e-paper newspaper life cycle in the European scenario.

3.4.1.3 Toxicological impacts

The pattern looked a bit different when it came to the toxicological impact categories. The production of the e-paper device was still the main contributor to three of the four toxicological impact categories: marine aquatic; human and terrestric toxicity (e.g. Figure 41). It was only the third largest contributor to freshwater aquatic toxicity where the incineration of plastic parts of the waste e-paper device was ranked as the main contributor followed by editorial work. The incineration was the second largest contributor to the human toxicity category.

The material recycling of 70% of the waste e-paper device was not included in the study due to lack of LCI data. The inclusion of material recycling could both mean increased and decreased impacts depending on the emissions from the material recycling processes as compared to emissions from virgin production.

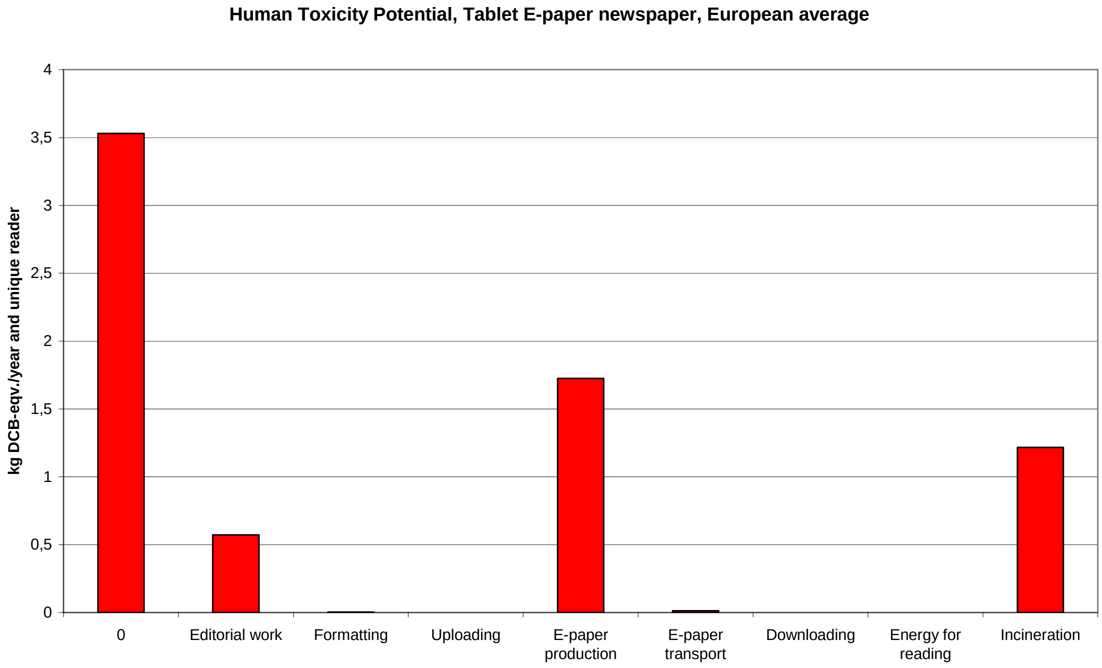


Figure 41. The human toxicity potential for different parts of the tablet e-paper newspaper life cycle in the European scenario.

3.4.1.4 Weighted results

The weighted values gave different results depending on which method that was used. Using the Ecotax 02 min weighting method, incineration of the waste e-paper device, editorial work and e-paper device production made out three equal parts of the total weighted value (Figure 42). Using the Ecotax 02 max or the Ecoindicator 99 (HA) weighting methods the e-paper device production made out the single main contribution to the total weighted value (Figure 43 and Figure 44). The other activity that contributed was the editorial work.

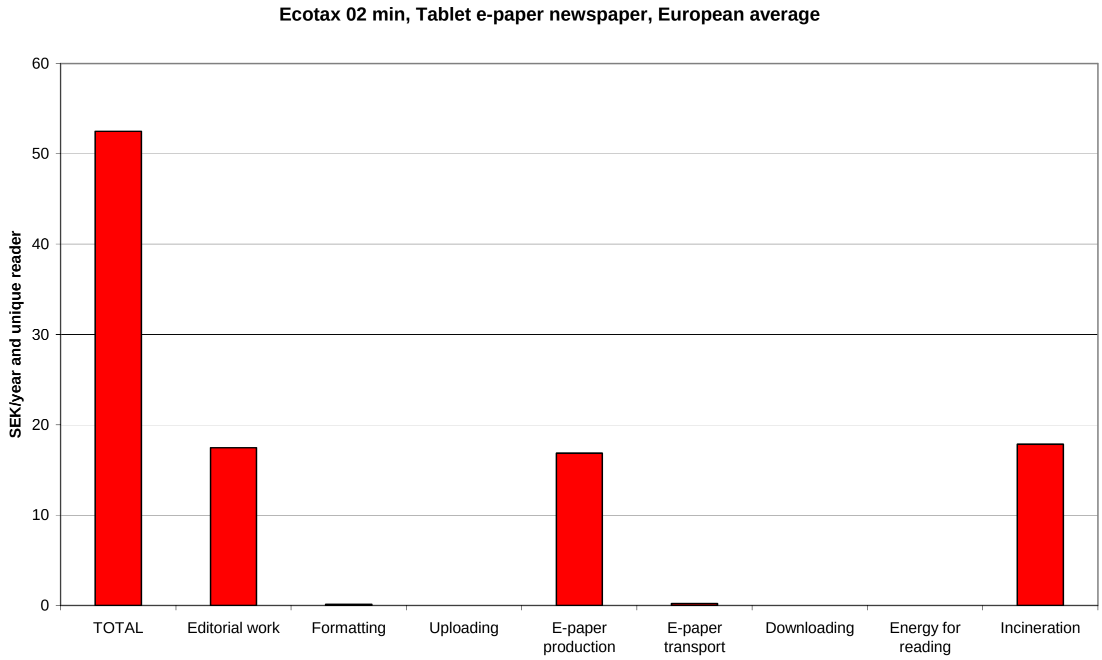


Figure 42. The total weighted values for different parts of the tablet e-paper newspaper life cycle in the European scenario using the Ecotax 02 min weighting method.

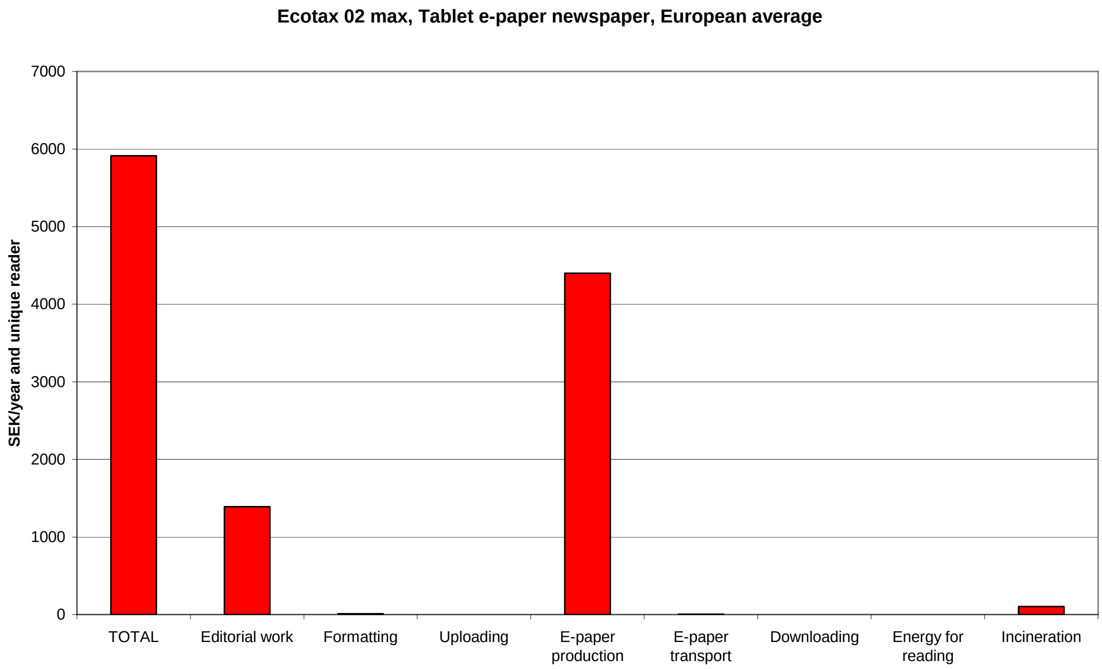


Figure 43. The total weighted values for different parts of the tablet e-paper newspaper life cycle in the European scenario using the Ecotax 02 max weighting method.

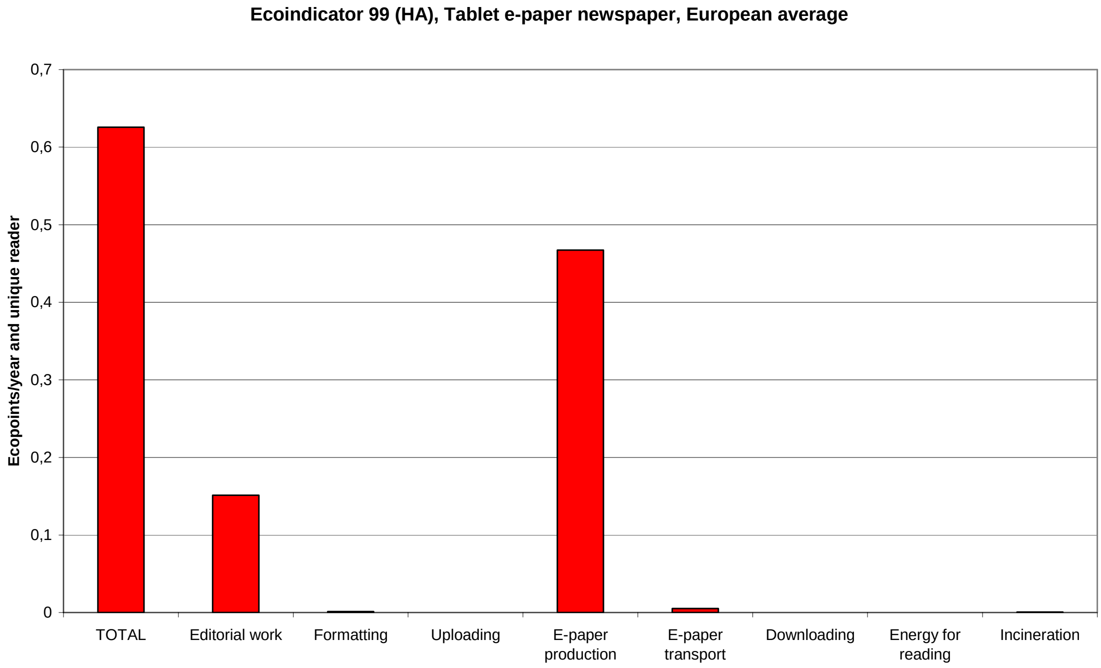


Figure 44. The total weighted values for different parts of the tablet e-paper newspaper life cycle in the European scenario using the Ecoindicator 99 (HA) weighting method.

Regarding the Ecotax min results, emissions from incineration of plastics, from electricity production and also from the production of the tablet e-paper (mainly from the production of the printed wiring boards (PWBs)) were the main contributions. The total weighted value was 52 SEK/year and unique reader. Using the max-version of Ecotax 02, the total weighted value was 5 900 SEK/year and unique reader and in this case emissions to air related to the tablet e-paper production (55%), and especially the production of the PWBs was the main contribution. With the Ecoindicator 99 (HA) the resources used (mainly natural gas and crude oil) made out about half of the total weighted value. The other main part was emissions of SO_2, NO_x and CO_2, mainly from the production of the tablet e-paper (mainly PWBs).

3.4.1.5 The e-ink screen

Data for the e-ink screen were missing in this study. However, a rough calculation was made to get an indication of the potential environmental impact of the screen. In this analysis the carbon black and titanium oxide pigments were studied. An estimation of the amount of these substances was made, which was intentionally an overestimation to see whether the impact of the pigments could be of any importance. The results of this rough analysis showed that the pigments, with the assumptions made, generally gave rise to one percent or less of the total potential environmental impact of the tablet e-paper product system.

3.4.2 Swedish scenario

3.4.2.1 Resources used

In the Swedish scenario the production of the e-paper device made out the largest part of the resource use impact, 75-90%. The other activity that contributed to this impact category was the editorial work (Figure 45). This result was the same, studying the abiotic depletion potential (ADP), the total energy in resources used or the abiotic exergy. The difference compared to the European scenario was small, as the e-paper production remained unchanged.

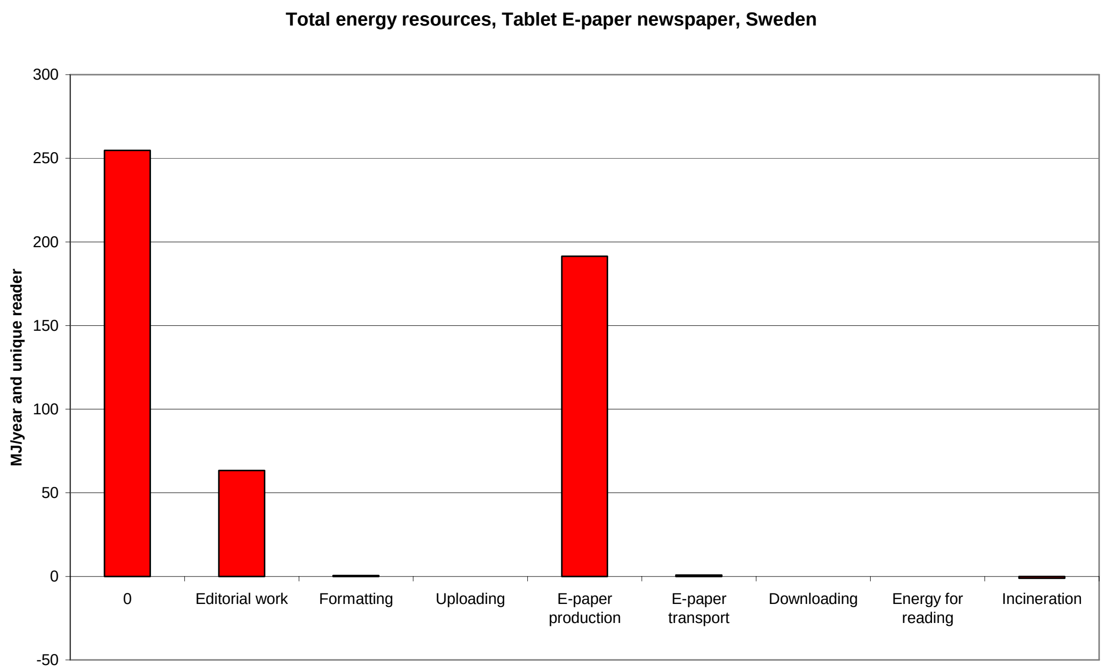


Figure 45. The total energy in the resources used for different parts of the tablet e-paper newspaper life cycle in the Swedish scenario.

3.4.2.2 Non-toxicological impacts

For the non-toxicological impact categories (acidification, eutrophication, ozone layer depletion, photooxidant formation and global warming) the production of the e-paper device made out the largest part of the impact and the other activity that contributed to these impact categories was the editorial work (e.g. Figure 46). The tablet e-paper newspaper product system studied gave rise to 10 kg CO_2-eqv./year and unique reader in the Swedish scenario. This can be compared to the 13 kg CO_2-eqv./year and unique reader in the European scenario. The difference is due to different electricity mixes for the electricity used for editorial work.

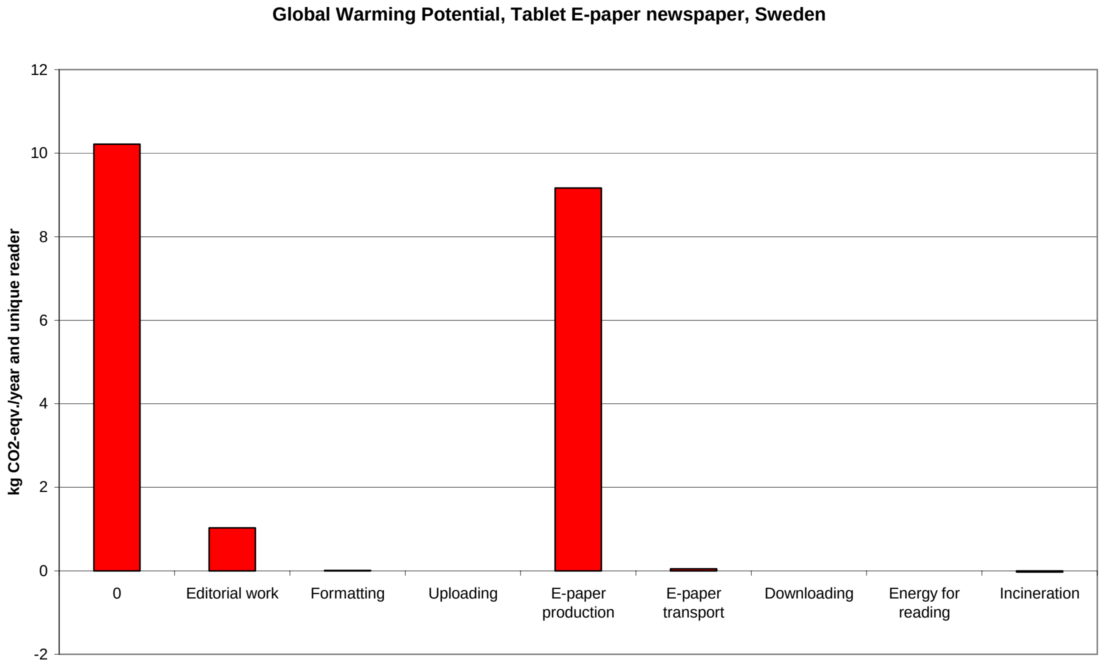


Figure 46. The potential global warming impact for different parts of the tablet e-paper newspaper life cycle in the Swedish scenario.

3.4.2.3 Toxicological impacts

As in the European scenario, the pattern looked a bit different when it came to the toxicological impact categories.

The production of the e-paper device was still the main contributor to marine aquatic and terrestric toxicity. Regarding the human toxicity potential e-paper production and incineration of parts of the waste tablet e-paper device made out roughly half of the total potential impact each (Figure 47). The incineration of plastic parts of the waste e-paper device was ranked as the main contributor to the freshwater aquatic toxicity category.

The material recycling of 70% of the waste e-paper device was not included in the study due to lack of LCI data. The inclusion of material recycling could both mean increased and decreased impacts depending on the emissions from the material recycling processes as compared to emissions from virgin production.

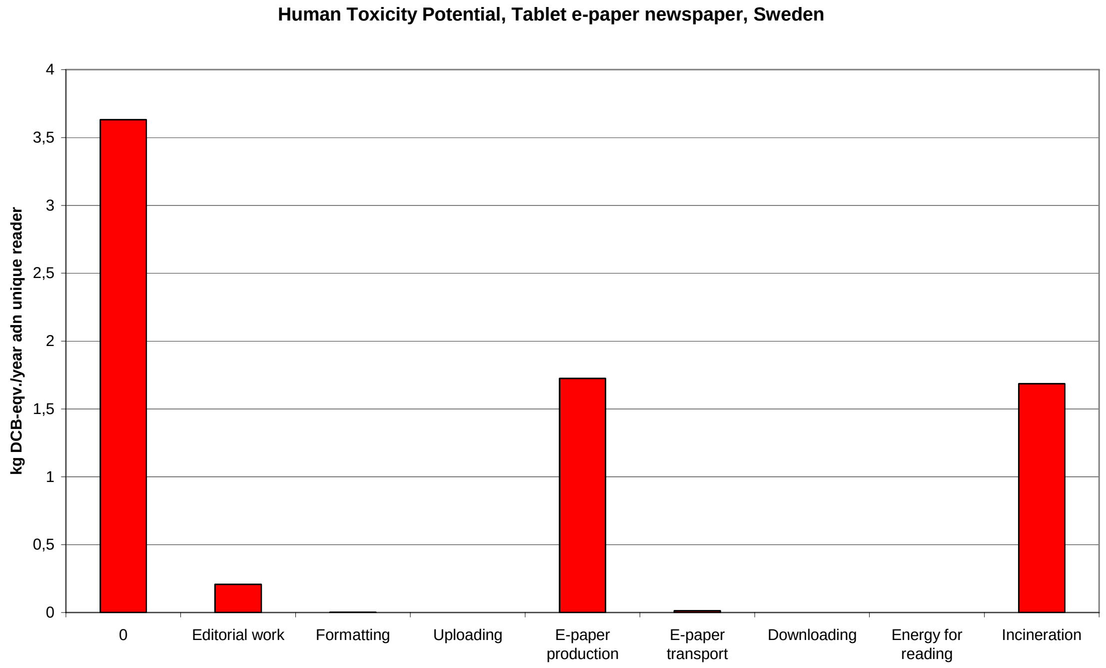


Figure 47. The human toxicity potential for different parts of the tablet e-paper newspaper life cycle in the Swedish scenario.

3.4.2.4 Weighted results

The weighted results gave different views depending on which weighting method that was used. Using the Ecotax 02 min weighting method, incineration of 30% of the waste tablet e-paper device stood for the largest part of the total weighted value, followed by e-paper production and thereafter editorial work (Figure 48). The difference compared to the European scenario was due to the energy recovered through the incineration of waste being credited by avoided Swedish electricity and district heating mix and European electricity and district heating mix, respectively (see 2.5), the European mixes with a larger total environmental impact, which was here avoided. The tablet e-paper production was unchanged and the impact of the editorial work was depending on the electricity used, Swedish and European electricity mix, respectively. Thus, in the Swedish scenario, the impact of incineration was higher and the impact of editorial work lower.

Using the Ecotax 02 max or the Ecoindicator 99 (HA) weighting methods the e-paper production made out the main contribution to the total weighted values (Figure 49 and Figure 50). The other activity that contributed was the editorial work, and in the Ecotax max weighting also the incineration of parts of the waste e-paper devices.

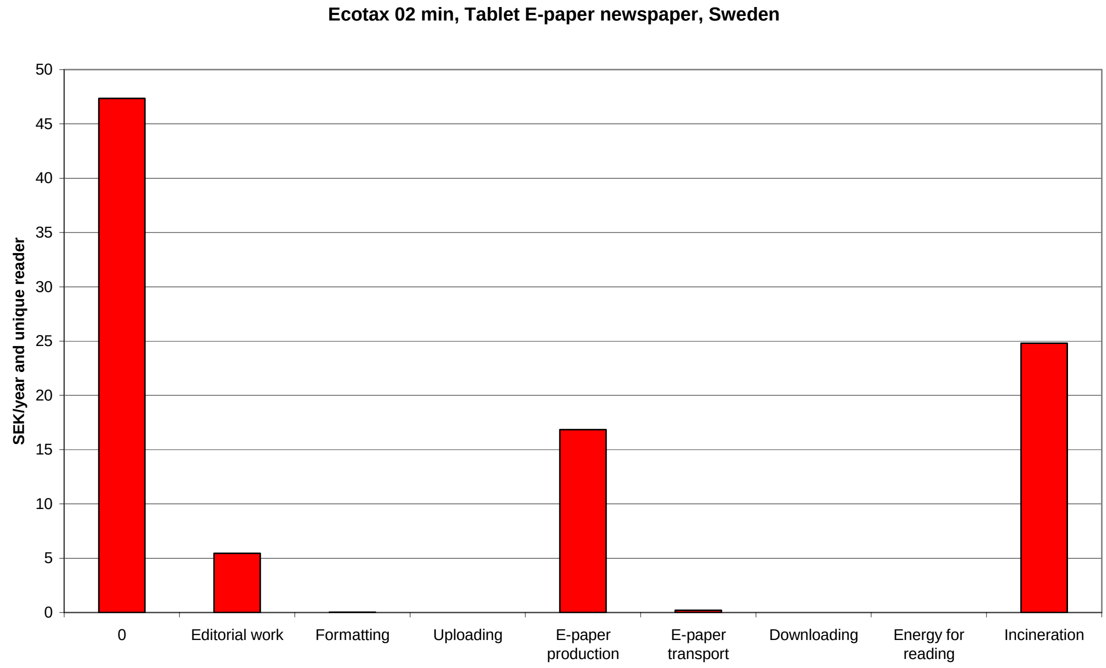


Figure 48. The total weighted values for different parts of the tablet e-paper newspaper life cycle in the Swedish scenario using the Ecotax 02 min weighting method.

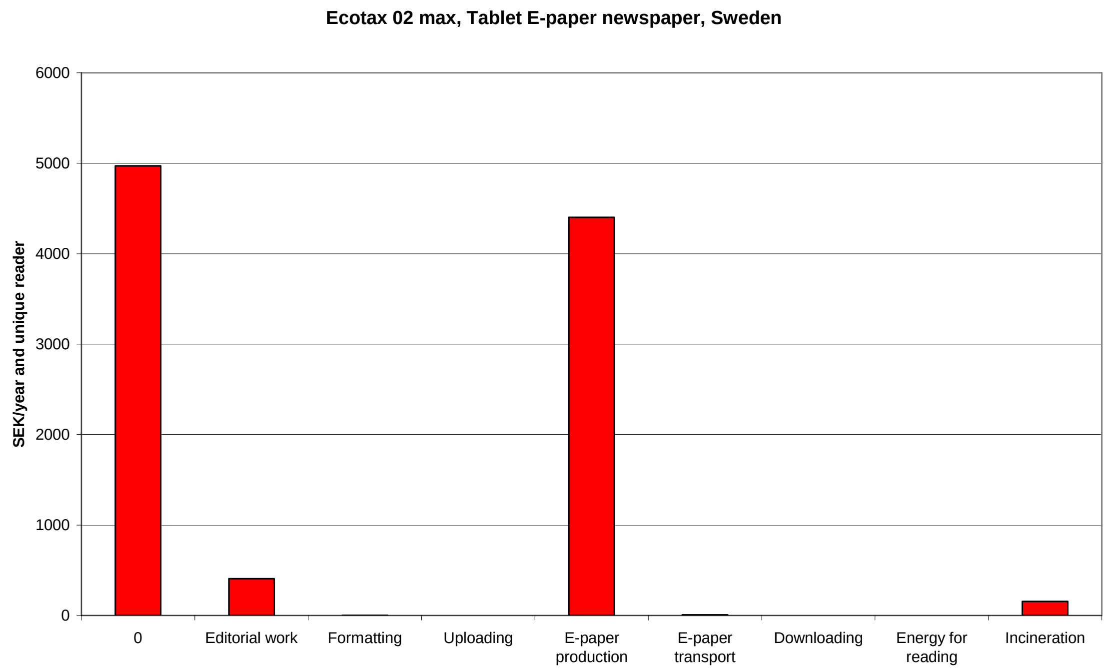


Figure 49. The total weighted values for different parts of the tablet e-paper newspaper life cycle in the Swedish scenario using the Ecotax 02 max weighting method.

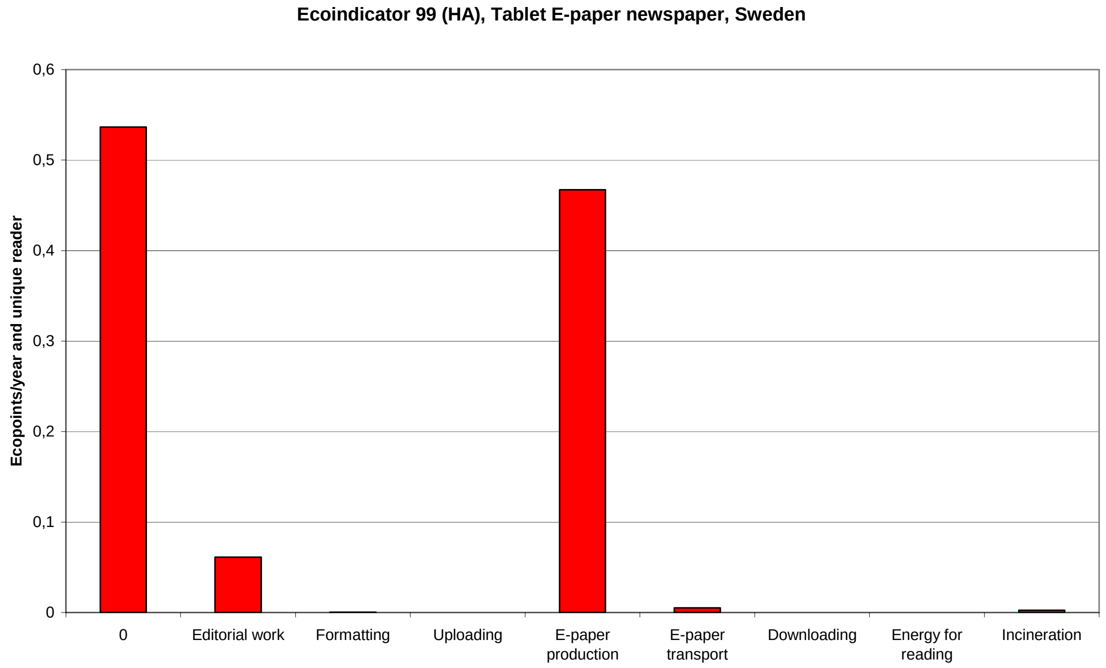


Figure 50. The total weighted values for different parts of the tablet e-paper newspaper life cycle in the Swedish scenario using the Ecoindicator 99 (HA) weighting method.

The total weighted value, using Ecotax 02 min, was 47 SEK/year and unique reader. Using the max-version of Ecotax 02, the total weighted value was 5 000 SEK/year and unique reader. The difference in total values was small compared to the European scenario, e-paper production and emissions from incineration remained unaltered. The main differences being the avoided energy and the electricity mix used for editorial work. The main difference in the total weighted values using the Ecoindicator weighting method concerned the weighted value of the editorial work.

3.4.2.5 The e-ink screen

Data for the e-ink screen was missing in this study. However, a rough calculation was made to get an indication of the potential environmental impact of the screen. See 3.4.1.5.

3.4.3 Tablet e-paper newspaper, including infrastructure

In one scenario the infrastructure for electronic distribution was included. However, due to lack of data old input-output data for USA were used. These data were not relevant since much has happened in the ICT sector since 1998. As no other data were available these data were used to get a rough estimation, illustrating whether the infrastructure may be important to consider in future studies. The results from the assessment of the tablet e-paper newspaper product system, including the infrastructure data, were that the impact from infrastructure was significant. However, the conclusions to be drawn were rather that this would be interesting to study more with newer and more precise data.

3.5 Comparison

A comparison was made between the different product systems. The comparison was made for the European and the Swedish scenario respectively. In the comparison two scenarios were used for the web based newspaper. Firstly, one where the web based newspaper was read for 10 minutes and 2.5 MB were downloaded and secondly, another where the reading time was increased to 30 minutes (the same time as assumed for the printed and e-paper newspapers) and 5.5 MB were down-loaded.

3.5.1.1 Resources used

When comparing the different product systems regarding resources used it should be kept in mind that the data for production of e-paper was based on several assumptions and that the material recycling of waste electronic products was not included. However, the results concerning resources were mainly affected by the resources used for energy generation.

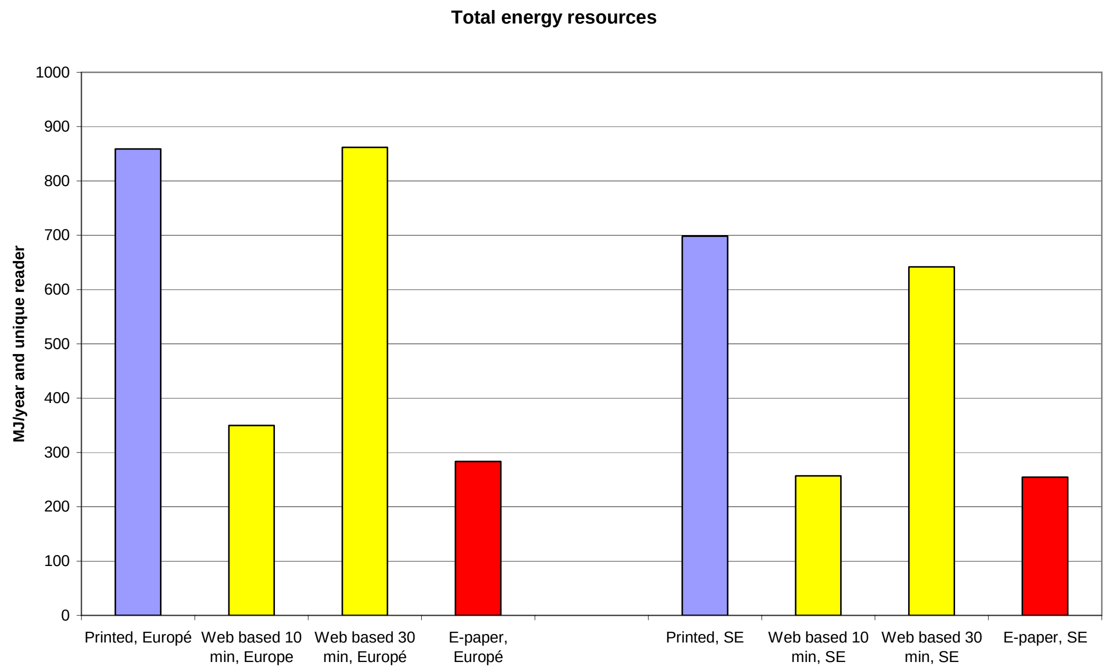


Figure 51. Comparison between printed newspaper, web based newspaper (reading time 10 and 30 minutes) and tablet e-paper newspaper. The comparison regarded total energy in resources used, and the systems were compared within the European and Swedish scenarios.

The total energy in resources used was for a one year consumption of newspaper for a unique reader between 860 and 280 MJ in the European scenario. The highest value of 860 MJ was the same for the printed newspaper and the web based newspaper with a reading time of 30 minutes. There was a rather small between the web based (10 min) and the tablet e-paper newspapers, and 350 and 280 MJ/year and unique reader, respectively. The pattern looks the same for the other resource use impact categories.

The energy in resources used was for the tablet e-paper mainly from the e-paper production. Since the reading of tablet e-paper newspaper was assumed to make out half of the total use time of the tablet e-paper, half of the resources used in production of the device were allocated to this product system. In the case of the web based newspaper, only 4% of the total use of the home computer and screen was assumed to be dedicated to reading the newspaper (10 minutes out of 4 hours). The life time of the tablet e-paper was also assumed to be shorter than that of the home computer and screen; 1 year and 5 years respectively.

The assessment of resource use resulted in a similar pattern for the Swedish scenario. The absolute values were a bit lower for the respective studied product systems, between 700 and 250 MJ per year and unique reader. In the Swedish scenario the difference between the web based (10 min) and the tablet e-paper newspapers was negligible when comparing total energy in resources used. When comparing the use of resources, through the abiotic depletion potential (ADP) and abiotic exergy, the e-paper newspaper had a larger impact than the web based (10 min) newspaper, since the main part of the energy for reading the web based newspaper was from hydropower.

3.5.1.2 Non-toxicological impacts

For eutrophication, ozone depletion and photooxidant formation the printed newspaper had the largest potential impact. Regarding acidification, the web based newspaper (30 min) was the major contributor, followed by the printed paper. On a lower level, the tablet e-paper and the web based (10 min) had similar values in the impact categories acidification, eutrophication and photooxidant formation. For ozone depletion, the potential impact was in the same range for the tablet e-paper, the web based newspaper (30 min) and the printed newspaper product system.

Regarding the global warming impact category (Figure 52), the web based newspaper (30 min) had the largest contribution in the European scenario (35 kg CO_2/year and unique reader). The difference between the web based (10 min) and the tablet e-paper newspapers was 1.5 kg CO_2/year and unique reader.

In the Swedish scenario, for eutrophication, ozone depletion and photooxidant formation the printed newspaper had the largest potential impact. Regarding acidification, printed newspaper and web based newspaper (30 min) had similar values.

The e-paper newspaper had higher values than the web based newspaper (10 min) in the categories acidification, ozone depletion and photooxidant formation. For eutrophication, the values were similar.

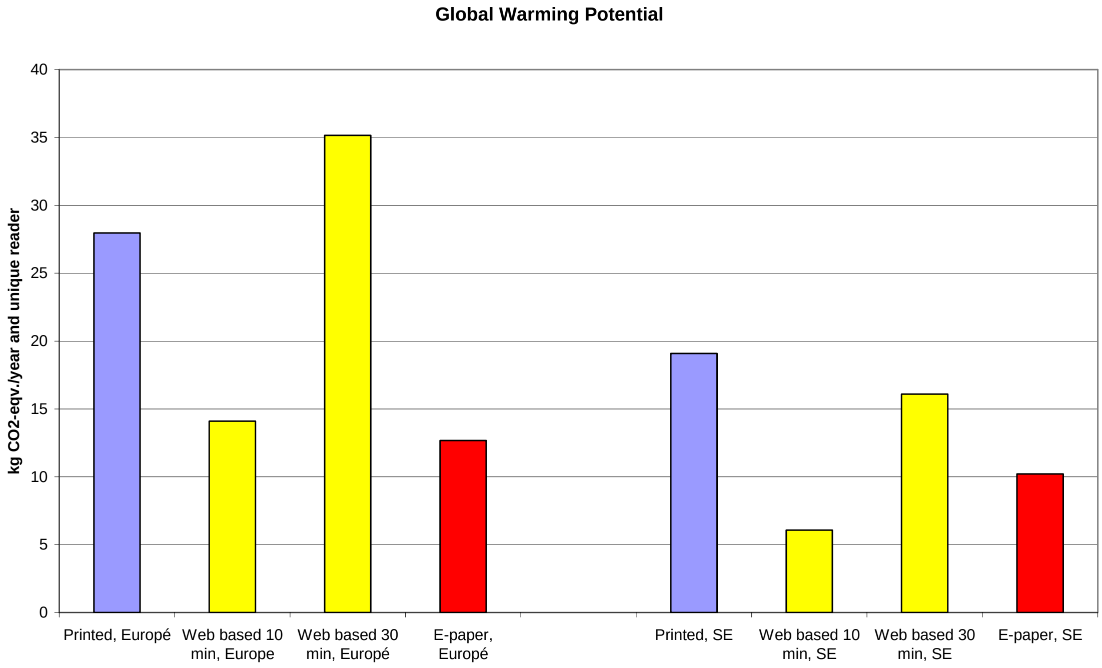


Figure 52. Comparison between printed newspaper, web based newspaper (reading time 10 and 30 minutes) and tablet e-paper newspaper. The comparison regarded global warming potential, and the systems were compared within the European and Swedish scenarios.

In the Swedish scenario, the printed newspaper had the largest global warming potential. The web-based newspaper had a lower global warming potential than the e-paper newspaper when 10 minutes of reading was assumed.

Differences between the ranking in the European and Swedish scenarios were mainly due to the fact that there were more major differences between the two scenarios for the printed and web based product systems than the tablet e-paper system. The major environmental impact of the tablet e-paper newspaper was in general caused by the tablet e-paper production and this process was the same in the European and the Swedish scenario. On the other hand, important aspects, such as the electricity mix used for reading the web based newspaper and for paper production, waste management of waste paper and fuel consumption for distribution were changed and affected the other product systems.

3.5.1.3 Toxicological impacts

The web based newspaper (30 min) had the largest potential impact in the marine aquatic toxicity and the human toxicity categories in the European and the Swedish scenario, followed by the printed newspaper (Figure 53). The printed newspaper had the largest potential freshwater aquatic and terrestric ecotoxicity impact.

The web based (10 min) and tablet e-paper newspapers had similar values in the marine aquatic toxicity and the human toxicity categories in the European scenario. In the freshwater aquatic and terrestric ecotoxicity impact categories the web based (10 min) had higher values than the tablet e-paper newspaper.

In the Swedish scenario the tablet e-paper had a larger potential impact than the web based (10 min) newspaper in the categories marine aquatic toxicity and human toxicity. In the marine aquatic toxicity category the value for the e-paper newspaper was similar to that of the printed newspaper. The values in the freshwater aquatic and terrestric ecotoxicity impact categories were similar for the web based (10 min) and tablet e-paper product systems.

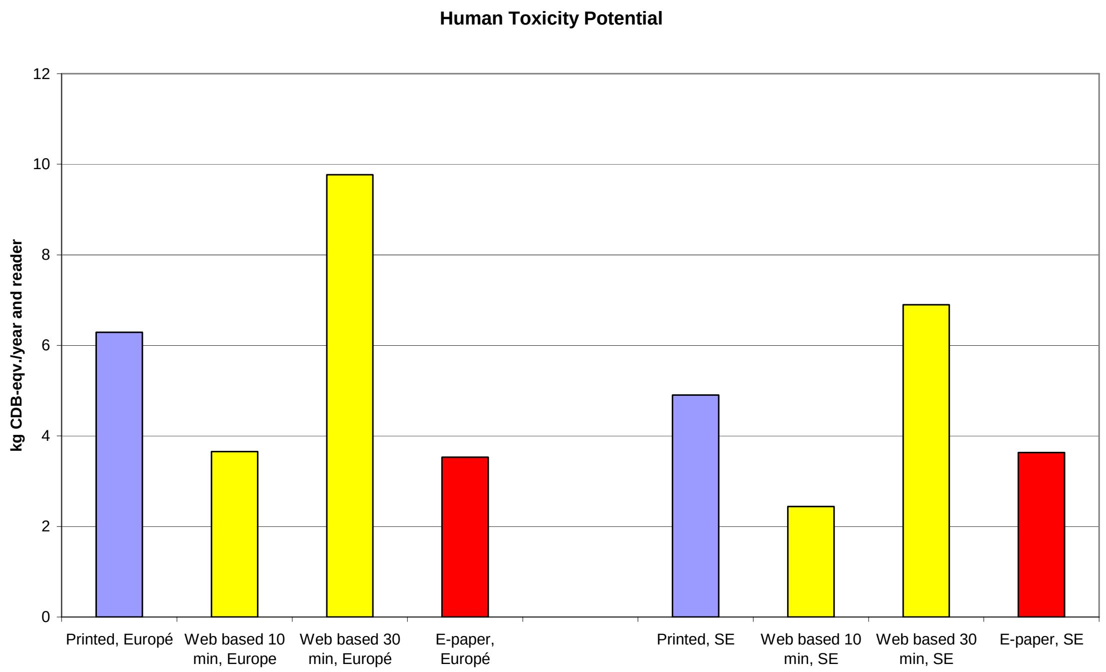


Figure 53. Comparison between printed newspaper, web based newspaper (reading time 10 and 30 minutes) and tablet e-paper newspaper. The comparison regarded human toxicity potential, and the systems were compared within the European and Swedish scenarios.

3.5.1.4 Weighted results

The weighted results showed that the printed newspaper and the web based (30 min) newspaper gave rise to the largest impacts. Using the Ecotax 02 min weighting method (Figure 54), the printed newspaper had the highest figures. When using the max version (Figure 55) of the same method the web based (30 min) newspaper resulted with the highest figures. This was due to different weighting values for emissions of various kinds and illustrates the inherent uncertainty of weighting.

In the Ecotax min weighting the web based (10 min) had a higher total value than the tablet e-paper newspaper, in the European scenario. In the Swedish scenario, the values were similar. In the max version, the total weighted values of the web based (10 min) newspaper and the e-paper newspaper were similar in the European scenario. In the Swedish scenario the tablet e-paper newspaper had a higher total value than the web based (10 min).

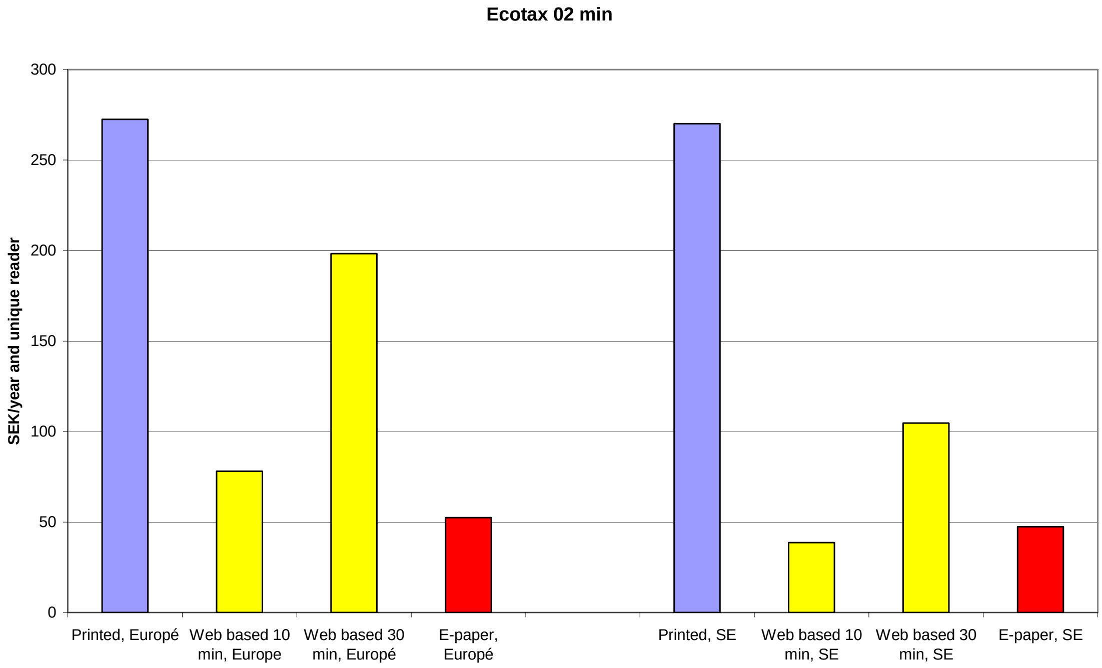


Figure 54. Comparison between printed newspaper, web based newspaper (reading time 10 and 30 minutes) and tablet e-paper newspaper. The comparison regarded total weighted values using the Ecotax min weighting method. The systems were compared within the European and Swedish scenarios.

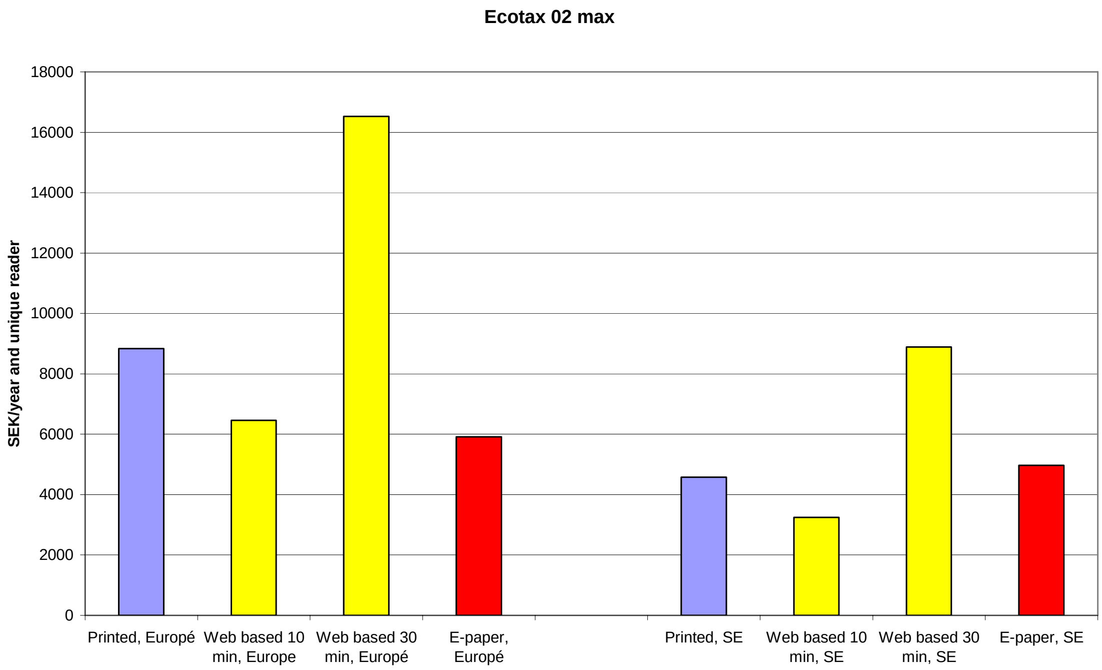


Figure 55. Comparison between printed newspaper, web based newspaper (reading time 10 and 30 minutes) and tablet e-paper newspaper. The comparison regarded total weighted values using the Ecotax max weighting method. The systems were compared within the European and Swedish scenarios.

Using the Ecoindicator 99 (HA) method the printed newspaper had the highest values, followed by the web based (30 min). The total weighted values of the web based (10min) newspaper and the e-paper newspaper were similar in the European scenario. In the Swedish scenario the tablet e-paper newspaper had a higher total value than the web based (10min).

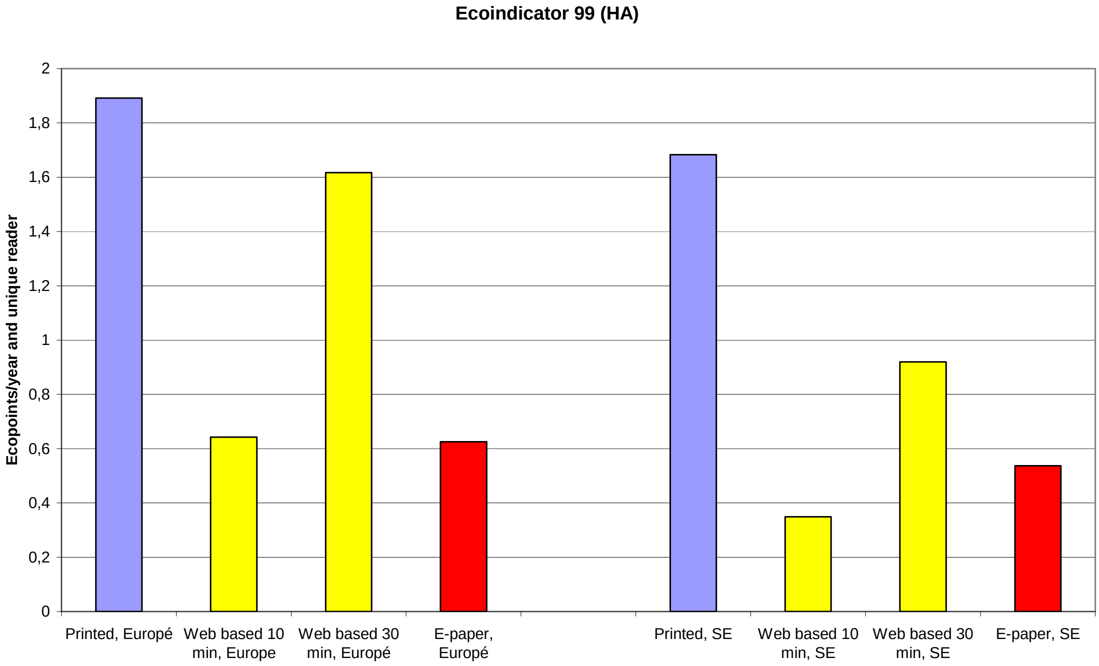


Figure 56. Comparison between printed newspaper, web based newspaper (reading time 10 and 30 minutes) and tablet e-paper newspaper. The comparison regarded total weighted values using the Ecoindicator 99 (HA) weighting method. The systems were compared within the European and Swedish scenarios.

In the three weightings respectively, the difference between the European and the Swedish scenario was the same, the Swedish figures were lower. The difference between the scenarios was in some cases large in some cases small. Generally, the difference was larger for the web based newspaper, since a main aspect for this product system was the electricity used when reading the newspaper. Altering the European electricity mix for the Swedish electricity mix made a difference from an environmental perspective. For the e-paper product system, the difference between the European and the Swedish scenario could be seen in the editorial work (changed electricity mix) and in the waste management (change in avoided energy production). For the printed newspaper system the changes were mainly the change in electricity mix; both for newsprint production, printing and editorial work, but also a change in distribution from urban to rural with a larger fuel consumption per newspaper in the Swedish scenario.

3.5.2 Missing data

There were some missing data in this screening LCA study. The major activities that were missing were the following:

- Journalist fieldwork (e.g. travel)
- Production of tablet e-paper e-ink screen
- E-infrastructure
- Recycling of electronic waste

In the case of the journalist fieldwork, this may be an important part if the journalists travel a lot and especially if the edition is small. As the energy used for editorial work at the office was a significant part of e.g. the total energy in resources used for the web based and the tablet e-paper newspaper systems the journalist fieldwork could be relevant from an environmental perspective. When it comes to comparison between the systems, the journalist fieldwork will not make any difference. With the same assumption as for the editorial work, the journalist fieldwork would have been split equally between the unique readers.

The production of the e-ink screen of the tablet e-paper was missing. The production and waste management of the screen could affect the environmental impact if e.g. the production of components or the assembly is energy consuming, if toxic substances are used or if the screen can not be recycled. A rough analysis of the pigments carbon black and titanium dioxide indicated that the potential environmental impact of the e-ink screen could be relevant.

Even if there was one scenario where input-output data on infrastructure for electronic distribution was used (see 2.7 and 3.4.3) these data were not satisfactory and thus in the study data on e-infrastructure is missing. As was shown by Kamburow (2004) this could be significant for the e-paper newspaper.

Waste management of the electronic products was assumed to be 70% recycling and 30% incineration with energy recovery. The material recycling into new metals, glass and plastics was not included in the model due to lack of data. The effect of including recycling depends on the process, whether it is energy consuming or if toxic substances are needed or emitted. The impact resources used would have been credited for the avoided production of new material, if recycling had been included.

4 Discussion and overall conclusions

Results from the screening LCA performed indicate that different activities part of the respective newspaper product systems contribute more or less to the potential environmental impact. The results of the respective systems will shortly be discussed below, as well as the comparison.

In general, it can be noted that the impact of the energy used for editorial work was shown to be notable in several cases. This was the result even though the journalist fieldwork, mainly the travel, was missing.

4.1 Printed newspaper

The main environmental impact of the printed newspaper was caused by the paper. This is in line with earlier studies, e.g. Enroth (2006) states that the use of paper (forestry, pulp and paper production) generally gives rise to 30-70% of the total environmental impact of printed paper products.

Other activities that were contributing to the potential environmental impact of the printed newspaper were, in the European scenario mainly printing, editorial work, prepress and paper transport. In this scenario, distribution had only a limited part in the total environmental impact. This was due to the other activities depending on European electricity mix, the paper transport was performed by truck and train (diesel and electric) and the distribution was assumed to be urban, with relatively low fuel consumption per newspaper. Regarding the data on distribution, the modelled transportation was not illustrating the driving behaviour of distribution, which may lead to differences regarding emissions; wear to the car, etc. The data on fuel consumption origins from data for newspaper companies in Sweden, thus the amount of fuel per newspaper was distribution specific. The emissions data for the distribution was however limited (see Table 2). The potential impact of the emissions may be discussed, since the emissions from distribution occur at a low level, close to the ground and maybe in densely populated areas. This can be compared to emissions from energy generation which often occurs at a high level, from chimneys. Thus the potential impact of emissions from distribution may be underestimated compared to e.g. energy generation. In addition, the data used here for distribution were average data. In reality there will be a distribution of data, which means that for specific situations, the environmental impacts can be significantly larger.

In the Swedish scenario the newsprint production gave rise to the largest environmental impact of the printed newspaper product system in general. Distribution, printing and to some extent editorial work, prepress and paper recycling were the main other activities contributing to the total impact. In the Swedish scenario the distribution was assumed to be rural with a higher fuel use per newspaper. This was reflected in the results, as distribution was the second largest contributor to the global warming potential and the largest contributor regarding ozone depletion and photooxidant formation.

The environmental performance of the printed newspaper has in this study been related to each unique reader. This means that the environmental impact of a single copy of the printed newspaper in this case has been split between 2.4 unique readers. The result would thus be different if the environmental performance per printed copy would have been studied.

4.2 Web based newspaper

The energy use for reading the web based newspaper was a main reason for the potential environmental impact, but not the only.

In the European case the energy for reading was the major reason for the environmental impact of the studied system. Editorial work and PC and screen production also made out part of the total environmental impact. Incineration of part of the waste PC and screen was significant in some of the toxicological impact categories.

Changing from the European perspective to the Swedish, the impact of the use phase was lowered, while the impact of the PC and screen remained. This was due to the difference in electricity mix, with a change to more hydro power in the use phase in the Swedish scenario. For example, the screen and PC production together gave rise to about 70% of the potential acidification and photo oxidant formation. The different total weighted value for the web based newspaper in the Swedish scenario illustrates the uncertainties regarding weighting and also regarding toxicological impacts in general. The three weighting methods (Ecotax02 min, Ecotax 02 max and Ecoindicator 99 (HA)) ranks, respectively, incineration of waste PC and screen, screen production and energy for reading as the activity with the largest total environmental impact.

The contribution to the total impact from the production of the PC and screen was highly sensitive to the assumed life time and the total use time per day of the equipment. In the case study it was assumed that the web based newspaper was read for 10 minutes/day and that the computer was used for a total time of 4 hours per day. If the total use time would be for example 2 hours per day, the impact caused by production (and waste management) of the PC and screen allocated to the web based newspaper life cycle would be roughly doubled.

For the web based newspaper, a scenario with print-out of 2 A4-pages per day on a home printer was studied. This was done only with the European perspective. This scenario showed an increase in environmental impact when printing the web based information. The potential environmental impact was, however, still lower than for the printed newspaper in the European scenario. The production, transportation and waste management of the printer was not included. Including these activities would add to the environmental impacts and could be of relevance for the final result.

4.3 Tablet e-paper newspaper

The production of the tablet e-paper device was the single largest part of the total environmental impact of the tablet e-paper newspaper life cycle. Editorial work, and for some impact categories also the incineration of parts of the electronic device (plastic waste) contributed to the rest of the environmental impact.

For the tablet e-paper newspaper, the use phase was negligible regarding environmental impact. The development of an electronic device that does not consume a lot of energy during the use phase has resulted in the shift of relative environmental importance towards the production of the electronic product and the waste management.

The pattern was similar in the European and the Swedish scenarios, since the main impact was from production performed in China. The difference was mainly regarding the emissions from energy used for the editorial work, as the electricity mix was altered. The relative impact of the waste incineration was generally higher in the Swedish scenario, since the avoided energy was of different origin.

The impact from the tablet e-paper device was in accordance with the PC and screen in the web based newspaper product system, highly sensitive to the assumed life time and the total use time per day of the equipment. In the study it was assumed that the tablet e-paper newspaper was read for 30 minutes/day and that the device was used for a total time of 1 hour per day. The lifetime of the tablet e-paper device was assumed to be one year. The environmental performance of the tablet e-paper newspaper will decrease with a longer lifetime.

In the study on cumulative energy use (Kamburow 2004) the distribution of the e-paper newspaper was the main activity contributing the most to the cumulative energy use. There was substantial difference concerning which kind of transference that was assumed, i.e. UMTS (Universal Mobile Telecommunication System), Internet or DAB. It has not been possible for us to compare the results in detail. However it is clear that there is a remarkable difference considering which activity of the life cycle that gives rise to the main impact. The study by Kamburow has the functional unit of reading eight news articles (one edition). The resulting energy use is 10 MJ and 50 MJ respectively for an e-paper newspaper distributed via Internet and UMTS respectively and this energy is almost only used for the distribution. This can be compared with our results were the total energy in resources used were 280 MJ/year and unique reader. If 50 MJ is used each day, as in the UMTS case, this would result in 18 000 MJ/year and unique reader.

Kamburows study results in 1.5 MJ and 2 MJ respectively for the printed newspaper and the web based newspaper (20 minutes reading), which is more in line with our results of 860 and 350 MJ/year and unique reader (860 for web based newspaper and 30 minutes reading).

4.4 Comparison

In the comparison between the different newspaper product systems, the results showed that the ranking from an environmental point of view was in general that tablet e-paper and the web based newspaper, with a shorter reading time (10 minutes per day), was giving rise to a lower environmental impact than the printed version. It should be noted that with a reading time of 30 minutes per day the environmental impact of the web based newspaper was often in the same range as the printed newspaper environmental impact, sometimes higher sometimes lower. The same result was presented by Hischier and Reichart (2001) in their comparison between printed newspaper, television and internet. Hischier and Reichart showed that using the Internet for around 25 minutes or watching the television for roughly 1.5 hours gave environmental impact of similar magnitude as a printed newspaper.

Yagita et al (2003) compared printed newspaper with web based newspaper regarding CO_2-emissions, excluding waste treatment. They concluded that the resulting emissions were dependent on whether a desktop or a notebook PC was used, as the notebook was using less energy. With their assumptions the web based newspaper gave rise to less CO_2-emission than the printed version as long as the PC was not used for more than 1.4 hours and 1.1 hours per day for notebook and desktop respectively. The emissions of the printed newspaper life cycle were calculated to be 0.32 kg CO_2/copy of newspaper (Yagita et al 2003). This could be compared to the results of this study recalculated to per copy of newspaper: 0.22 kg CO_2/copy of newspaper in the European scenario and 0.15 kg CO_2/copy of newspaper in the Swedish scenario, which is in the same range. Yagita et al. compared the printed newspaper copy to the web based newspaper, and did not regard the possibility of more than one reader per copy.

The results of this study indicated that in many impact categories the difference was small between the web based newspaper with 10 minutes reading time and the tablet e-paper newspaper. Generally the web based newspaper had relatively higher values in the European scenario and in the Swedish scenario the e-paper newspaper in some cases had a higher impact than the web based.

In the comparison by Kamburow (2004), the e-paper newspaper results with the largest cumulative energy use (Kumulierten Primärenergieaufwandes, KEA) as compared to printed and on-line newspapers. The energy figure is roughly 5 and 25 times higher for the e-paper newspaper when distributing the electronic news via Internet and UMTS respectively. As we have not covered the e-infrastructure in our study this could be interesting to look into.

It should be noted that the data and the modelling of the e-paper production in our study was uncertain and that more detailed studies need to be done. It can also be discussed whether it is relevant to compare 10 minutes reading on the web with 30 minutes reading on a tablet e-paper. The function and benefit may be too different. However, what can be said is that the production and waste management of electronic devices will become of more relative importance when the energy for using the product is lowered. In the cases when the use phase was in Sweden and the production of the device in China the respective electricity mixes made a difference too. In the Nordel electricity mix 66% of the energy sources were from renewable energy and in the China mix the renewable energy sources amounted to 18% (coal was 72%).

In the present study, the newspaper reading of one unique reader during one year was considered. This means that a copy of the printed newspaper was shared, in this case between 2.4 readers. This is similar to the possible sharing of the home computer for reading the web based news. In the case of the tablet e-paper newspaper, the assumption was that the e-paper device was personal and that there was one unique reader per tablet e-paper device. If the tablet e-paper would have been shared between people, the environmental impact related to one unique reader would have decreased. In addition, the environmental impact of the two studied product systems web based and tablet e-paper newspaper were sensitive to the possible multi-purposes for use of the devices. The more benefit from the device the more benefit to split the environmental impact caused by production and waste management of the device between.

In our study, screening data was in some cases used and some data were missing. Main LCI data lacking for the web based and tablet e-paper systems included the electronic distribution infrastructure and the material recycling of parts of the waste electronic devices. For the tablet e-paper, in addition data for the e-ink screen was missing. For the printed newspaper, data on the production of certain supply chemicals, etc was missing. These missing data may have resulted in an underestimation of the potential environmental impact. For material recycling the effect of the missing data is difficult to judge. Including material recycling in a future study would lead to lower resource use in a life cycle perspective of the PC, screen and tablet e-paper. In addition, other impact categories would be affected. In what way they would be affected depends on the processes (energy use, use of chemicals, emissions, etc.) for recycling and for the avoided virgin production. According to Choi et al (2006) a higher rate of recycling leads to lower total environmental burden of a PC. Opposite to this conclusion, Lu et al (2006) state that increasing the recycling rate of notebooks will lead to increasing environmental impact, mainly caused by the control unit that contains several chemicals and heavy metals. In the latter study the avoided production of materials was not included; recycling was compared to other waste management options. It should be considered that recycling may result in substantial amounts of emissions if the product contains chemicals and heavy metals, however this is a question of the design of the product and the substances will end up somewhere irrelevant of waste management option chosen.

The production and use of infrastructure for electronic distribution was not covered in this study in a relevant way. The rough calculation based on old input-output data gave an indication that this could be worth to study in more detail. Gard and Keoleian (2002) in their study on digital and printed Journal articles included the networking infrastructure, but not networking transmission infrastructure. The networking infrastructure, e.g. routers, hubs and switches, were found to have “a negligible impact on energy burden”. In the case of the e-paper newspaper studied here, the infrastructure could be relevant since the whole newspaper was sent twice per day to all readers, independent on if they want to read it or not. This made a difference to the web based newspaper where the reader only used the infrastructure when interested in reading something.

Not all impact categories were equally well covered. In general, LCA covers energy related resources and emissions better than process specific and material specific impacts. Especially emissions of toxicological concern is often lacking in LCAs (Finnveden, 2000). This means that the results for the toxicological impact categories should be interpreted with special care. It also means that an LCA can not replace risk assessments of chemicals used. It may be of special importance for producers and users of the tablet e-paper to check the chemicals used in the product in order to avoid backlashes. It should thus be checked which types of hazardous chemicals are used in the product. As previously mentioned, the composition and design of the tablet e-paper is relevant regarding the possibility to recycle the main part of the material.

Development potential for all systems could be seen. For the tablet e-paper it can be assumed that the potential is rather large, since it is a new product system which is under development. The relative environmental impacts may be lowered through prolonged lifetime, more use for other purposes/combination of several functions in one product, considering the waste management, etc. In the development of the product, it should be considered that the product should not end up as hazardous waste after fulfilling its purpose since this will lead, not only to environmental impact, but also to more costly waste management. The potential development areas are similar for the web based system, including also a decrease of energy use during the use phase. The potential for improving the environmental performance of the printed newspaper can be found in more energy efficient pulp and paper production, using less non-renewable energy sources, etc. In addition, more efficient distribution could decrease the environmental impact of the system.

In this study we have studied the potential environmental impact of three newspaper product systems. The function or benefit of these systems may be discussed. This is of high importance, since the environmental impact should be related to the benefit gained. It was not possible to cover this issue within the scope of this study, but it should be noted that for example the printed newspaper could fulfil different purposes than the web based newspaper (e.g. Holmqvist et al, 2003 and Holsanova and Holmqvist, 2004).

4.5 Future studies

As the tablet e-paper is a new product, it would be of interest to look into some of the activities part of the life cycle in more detail. The production of the e-ink screen in particular, but also a more comprehensive and specific LCI of the tablet e-paper production would be interesting since this was where the main environmental impact was seen in the screening LCA of the tablet e-paper newspaper. Furthermore to have the tablet e-paper device examined by a waste recycling/sorting company to get product specific data on the waste management would be beneficial. The possible impact of the infrastructure for e-distribution could be relevant to consider as well.

As mentioned above, future studies comparing different ways of presenting and distributing news, etc should include the discussion on difference in function or benefit of the systems.

4.6 Overall conclusions

Some overall conclusions of the respective studied systems are the following:

- The main environmental impact of the printed newspaper was caused by the paper.
- The main environmental impact of the web based newspaper was caused by the energy use for reading on the screen.
- The main environmental impact of the tablet e-paper newspaper was caused by the production of the tablet e-paper.

Some overall conclusions of the case study are the following:

- Tablet e-paper has a potential for decreasing environmental impact of newspaper consumption.
- Key aspects for the environmental performance include:
    - Number of readers per copy of printed and tablet e-paper newspapers
    - Reading time for web based newspaper
    - Lifetime of electronic devices
    - Multi-use of electronic devices
- The production and waste management/disposal of the electronic devices become significant activities as the energy use during the use phase is decreased, i.e. the tablet e-paper.
- The energy use for editorial work becomes significant as the energy use during the use phase is decreased, i.e. the tablet e-paper and even in the other product systems the editorial work is notable.
- Many of the major contributions to the impact categorised are related to the use of electricity.

Some overall conclusions related to the methodology are the following:

- The definition of the functional unit in comparison between alternatives is not straightforward.
- Comparing a new area like the ICT sector to more established technologies leads to differences in availability of data.

Areas where future research would be relevant and interesting include:

- Better inventory data for tablet e-paper production, including intermediate upstream processes.
- Better data on additives for all three systems.
- The investigation of waste management options for the e-paper device.
- The consideration of potential environmental impacts of the e-infrastructure with a life cycle perspective.
- Combinations of uses of different e-media and printed media fulfilling different needs. Further discussions on the different functions fulfilled/benefits gained from the different product systems studied.

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5.3 Data sources

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6 List of Appendices

The appendices are available electronically at:

www.sus.kth.se

www.infra.kth.se/fms/publikationer.htm

Appendix 1 Processes and data sources

1.1 Printed Newspaper

1.2 Web based Newspaper

1.3 Web based Newspaper with printout

1.4 Tablet e-paper Newspaper

Appendix 2 LCI data

2.1 Printed Newspaper, European scenario

2.2 Printed Newspaper, Swedish scenario

2.3 Web based Newspaper, European scenario

2.4 Web based Newspaper, Swedish scenario

2.5 Web based Newspaper with printout

2.6 Web based Newspaper 30 minutes reading, European scenario

2.7 Web based Newspaper 30 minutes reading, Swedish scenario

2.8 Tablet e-paper Newspaper, European scenario

2.9 Tablet e-paper Newspaper, Swedish scenario

Appendix 3 Data not published in this form earlier

3.1 PC production

3.2 Screen production

3.3 Tablet e-paper production

Appendix 4 Characterised and weighted results

4.1 Printed Newspaper, European scenario

4.2 Printed Newspaper, Swedish scenario

4.3 Web based Newspaper, European scenario

4.4 Web based Newspaper, Swedish scenario

4.5 Web based Newspaper with printout

4.6 Web based Newspaper 30 minutes reading, European scenario

4.7 Web based Newspaper 30 minutes reading, Swedish scenario

4.8 Tablet e-paper Newspaper, European scenario

4.9 Tablet e-paper Newspaper, Swedish scenario

4.10 Comparison, European scenario

4.11 Comparison, Swedish scenario