



**Environmental impacts from  
digital solutions as an alternative  
to conventional paper-based  
solutions**

**Final report**

**Anders Schmidt and Nanja Hedal Kløverpris**

**FORCE Technology  
Applied Environmental Assessment  
Hjortekærsvej 99  
DK-2800 Lyngby**

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**e-mail: [acs@force.dk](mailto:acs@force.dk)**

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# Table of contents

<b>PREFACE</b> .....	<b>5</b>
<b>1 SUMMARY</b> .....	<b>7</b>
<b>1.1 RESULTS</b> .....	<b>7</b>
<b>1.2 SENSITIVITY ANALYSIS</b> .....	<b>9</b>
<b>1.3 CONCLUSIONS</b> .....	<b>10</b>
<b>2 SAMMENFATNING</b> .....	<b>11</b>
<b>2.1 BAGGRUND</b> .....	<b>11</b>
<b>2.2 UNDERSØGELSENS OMFANG</b> .....	<b>11</b>
<b>2.3 RESULTATER</b> .....	<b>12</b>
2.3.1 HVOR STOR ER FORDELEN VED E-BOKS DISTRIBUTION? .....	12
2.3.2 HVAD ER DEN STØRSTE FORDEL? .....	13
2.3.3 HVOR LIGGER DE VÆSENTLIGSTE MILJØBELASTNINGER I E-BOKS SYSTEMET? .....	15
<b>2.4 RESULTATERNE ER ROBUSTE</b> .....	<b>15</b>
2.4.1 TID BRUGT PÅ LÆSNING.....	15
2.4.2 HVOR OFTE SKRIVES ET E-BOKS DOKUMENT UD? .....	16
2.4.3 BRUG AF MODERNE IT Udstyr .....	17
2.4.4 BEHANDLING AF PAPIRAFFALD .....	18
<b>2.5 KONKLUSIONER</b> .....	<b>19</b>
<b>3 INTRODUCTION</b> .....	<b>21</b>
<b>4 GOAL OF THE STUDY</b> .....	<b>21</b>
<b>5 SCOPE OF THE STUDY</b> .....	<b>21</b>
<b>5.1 FUNCTIONAL UNIT</b> .....	<b>22</b>
<b>5.2 LCA APPROACH</b> .....	<b>22</b>
5.2.1 CONSEQUENTIAL LCA.....	22
5.2.2 IMPACT ASSESSMENT .....	22
5.2.3 CALCULATION TOOL AND DATA SOURCES.....	23
<b>5.3 SYSTEM BOUNDARIES – GENERAL CONSIDERATIONS</b> .....	<b>24</b>
<b>6 INVENTORY ANALYSIS</b> .....	<b>25</b>
<b>6.1 THE AVERAGE DOCUMENT</b> .....	<b>25</b>
<b>6.2 COMMON ACTIVITIES FOR E-BOKS AND CONVENTIONAL DISTRIBUTION</b> .....	<b>26</b>
6.2.1 PAPER PRODUCTION.....	26
6.2.2 END-OF-LIFE OF PAPER .....	26
6.2.3 PRODUCTION AND CONSUMPTION OF ELECTRICITY .....	28
<b>6.3 THE E-BOKS SYSTEM</b> .....	<b>29</b>
6.3.1 ACTIVITIES AT E-BOKS’ CLIENTS .....	29
6.3.2 E-BOKS’ ACTIVITIES .....	30
6.3.3 DISTRIBUTION AND TRANSMISSION OF E-BOKS’ DOCUMENTS .....	31

6.3.4	DOMESTIC VIEWING OF E-BOKS DOCUMENTS .....	31
6.3.5	DOMESTIC PRINTING OF E-BOKS DOCUMENTS .....	33
6.3.6	END-OF-LIFE OF PRINTED DOCUMENTS .....	34
<b>6.4</b>	<b>THE CONVENTIONAL SYSTEM.....</b>	<b>34</b>
6.4.1	PRODUCTION OF ENVELOPES .....	35
6.4.2	PRINTING AND ENVELOPING OF DOCUMENTS .....	35
6.4.3	DISTRIBUTION OF LETTERS .....	36
6.4.4	END-OF-LIFE OF PRINTED DOCUMENTS AND ENVELOPES .....	36
<b>6.5</b>	<b>DATA PROCESSES AND DATA QUALITY.....</b>	<b>37</b>
<b>7</b>	<b><u>RESULTS OF THE IMPACT ASSESSMENT .....</u></b>	<b><u>38</u></b>
<b>7.1</b>	<b>THE E-BOKS SYSTEM .....</b>	<b>38</b>
<b>7.2</b>	<b>THE CONVENTIONAL SYSTEM.....</b>	<b>40</b>
<b>7.3</b>	<b>CONSEQUENCES OF CHANGING TO ELECTRONIC DISTRIBUTION .....</b>	<b>42</b>
7.3.1	BENEFIT FOR THE ENVIRONMENT IN ALL EXAMINED IMPACT CATEGORIES .....	43
7.3.2	WHICH BENEFIT IS MOST IMPORTANT? .....	43
<b>7.4</b>	<b>SENSITIVITY ANALYSIS.....</b>	<b>45</b>
7.4.1	PRINTING FREQUENCY .....	45
7.4.2	END-OF-LIFE OF PAPER AND ENVELOPES .....	46
7.4.3	TIME USED TO VIEW DOCUMENTS.....	47
7.4.4	ALTERNATIVE SPECIFICATIONS OF IT EQUIPMENT .....	49
7.4.5	SENSITIVITY ANALYSIS – SUMMARY .....	50
<b>8</b>	<b><u>DISCUSSION AND CONCLUSIONS.....</u></b>	<b><u>52</u></b>
<b>8.1</b>	<b>ENVIRONMENTAL CONSEQUENCES .....</b>	<b>52</b>
<b>8.2</b>	<b>SENSITIVITY ANALYSIS.....</b>	<b>52</b>
8.2.1	VIEWING TIME .....	53
8.2.2	END-OF-LIFE OF PAPER AND ENVELOPES .....	53
8.2.3	PRINTING FREQUENCY .....	54
8.2.4	IT EQUIPMENT.....	54
<b>8.3</b>	<b>IMPORTANT FEATURES OF THE EXAMINED SYSTEMS .....</b>	<b>54</b>
8.3.1	THE E-BOKS SYSTEM .....	54
8.3.2	THE CONVENTIONAL DISTRIBUTION SYSTEM .....	55
<b>8.4</b>	<b>CONCLUSIONS.....</b>	<b>55</b>
	<b><u>REFERENCES .....</u></b>	<b><u>57</u></b>

## Preface

The study was initiated by e-Boks ultimo 2008 with FORCE Technology as consultants. The background for the study was an interest in being able to document the environment properties of the e-Boks concept in a life cycle perspective. Another aim was to be able to compare the performance of the e-Boks system to the conventional distribution system, using ordinary mail, eventually using the results to give e-Boks a competitive edge.

When comparing different products in a Life Cycle Assessment, the International Standard Organisation (ISO) strongly recommends that a critical review panel examines the study, e.g. to judge whether the conclusions made are appropriate from a scientific point of view.

In the present project, however, a different approach was taken, aiming at involving a wide range of stakeholders from the beginning. A one-day workshop was held in February with experts and interested parties from the following organisations, companies and agencies being invited:

- Danish Environmental Protection Agency (Mariane Hounum, Mette-Lise Jensen)
- Danish National IT and Telecom Agency (Peter Schliemann)
- Danish Energy Agency (invited, did not participate)
- Danske Bank (Kristian Højland)
- KMD (Trine Thykier)
- The Danish Society for Nature Conservation (Christian Poll)
- e-Boks (Henrik Andersen, Marianne Wier)
- Post Danmark (Søren Boas (invited, did not participate))

At the workshop, the goal and scope of the study was discussed in detail, with each of the participants adding valuable knowledge from their fields of expertise. Unfortunately, Post Danmark could not devote resources to participate at the workshop, but they have at several later occasions provided very valuable input regarding the conventional system – an input which the project group has sought to include in their model in a representative way.

Following completion of the draft final report in mid-April it was distributed to all participants in the workshop, giving the possibility of amending errors and improve the general quality of the study and the report. Most comments received were taken into account in the final report.

The project group and e-Boks wish to thank all the people who contributed to the project, not only those mentioned above but also those who were interviewed by telephone and mail during the study.

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# 1 Summary

This study examines the environmental consequences of changing from conventional distribution of automatically generated documents by ordinary mail to electronic distribution using the e-Boks system.

The method used in the study is a consequential Life Cycle Assessment, examining the processes affected by a change of way of distribution for the whole life cycle of the documents. There is for example an increased use of electricity (generated in coal-based power plants) for storage of documents at KMD A/S and for viewing of the documents by the users of e-Boks. At the same time there is a decreased use of paper for documents and envelopes since all documents are distributed electronically, and the consumption of fuel for distribution of ordinary mail is also reduced.

The calculations concern all 98.5 million documents distributed in the e-Boks system in 2008. If not distributed by e-Boks, the documents would have been produced in paper format (average 1.8 pages plus an envelope) and distributed as an integral part of the postal services provided by Post Danmark. For the e-Boks system, the most important assumptions are that the users of e-Boks do not purchase a computer for this specific task alone and therefore environmental impacts from computer production have not been included. It is also assumed that it takes 3.25 minutes of computer use to view each document, and finally it is assumed that 15% of the documents are printed by the users.

The study focuses on global (climate change) and regional (e.g. acidification and smog formation) environmental impacts, together with consumption of fossil and renewable energy. Only little attention is paid to potential local impacts on ecosystems and human health.

## 1.1 Results

The environmental consequences of using e-Boks as an alternative to conventional distribution of documents are calculated by subtracting the impacts of the conventional system from the impacts of the e-Boks system. Negative results thus express that the environmental impacts are reduced and a benefit for the environment is achieved.

The results of the baseline scenario are shown in Table 1. The changes are negative in all categories, indicating that the contribution to the examined impacts is smaller in the e-Boks system. With the given preconditions there is thus an almost unambiguous benefit for the environment with a change to e-Boks distribution of automatically generated documents.

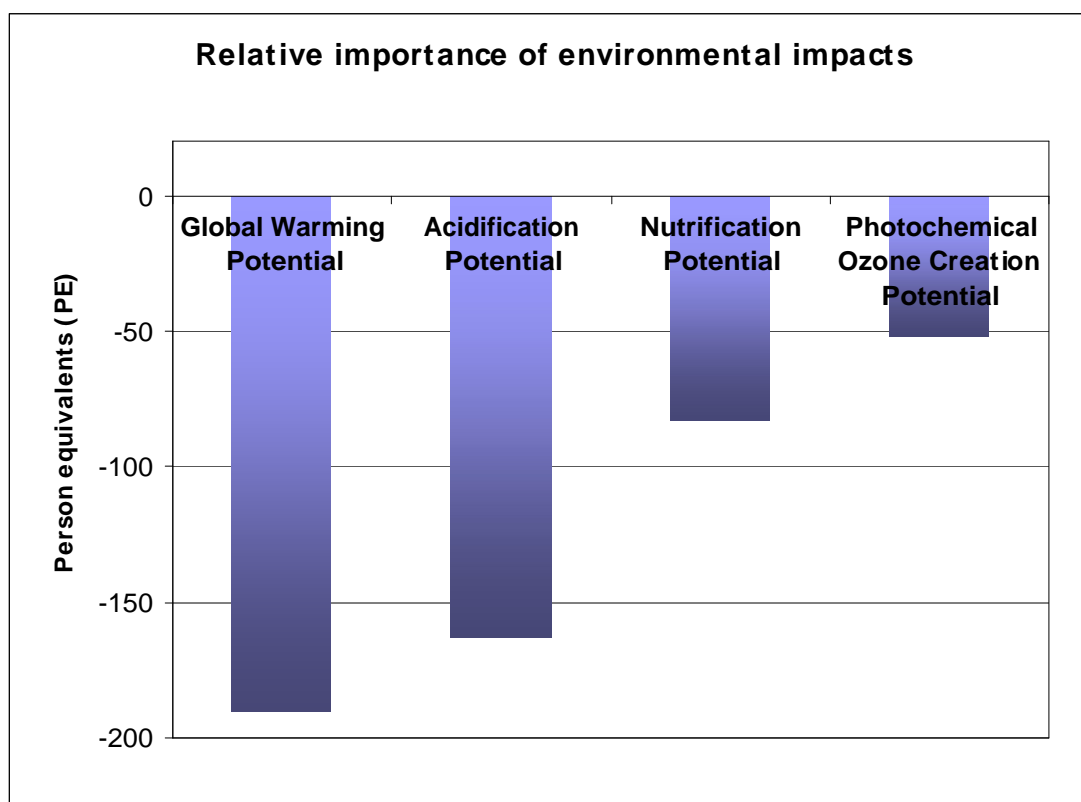
**Table 1. Changes in the environmental impacts and energy use as a consequence of distributing 98.5 million documents through e-Boks instead of by ordinary mail**

Impact category	Unit	Change
Global Warming Potential	kg CO <sub>2</sub> -eq.	-1,652,496
Acidification Potential	kg SO <sub>2</sub> -eq.	-16,415
Nutrication Potential	kg NO <sub>3</sub> -eq.	-21,493
Photochemical Ozone Creation Potential	kg C <sub>2</sub> H <sub>4</sub> - eq.	-1,039
Total energy consumption	MJ	-24,675,481

All results are normalised with respect to the impacts caused by an average citizen in the affected geographical area, the so-called "Person Equivalent" or PE. The Person Equivalent is calculated as the background impact over the course of one year caused by one person in the area for which the impact is computed. As an example, the average Danish citizen contributes to climate change with 8,700 kg CO<sub>2</sub>-equivalents and 101 kg SO<sub>2</sub>-equivalents. When

normalising the results, all impacts are addressed by the same unit, giving the possibility of identifying which results are potentially of most importance.

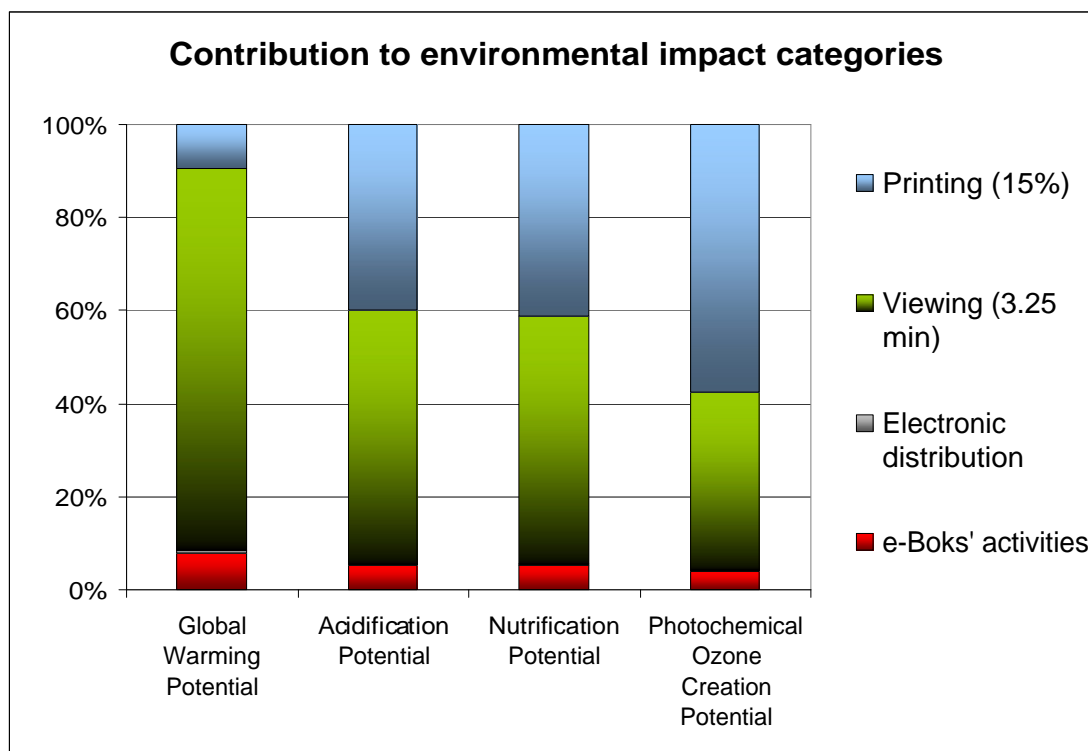
The normalised results are presented in Figure 1.



**Figure 1. Normalised environmental impacts as caused by a change from ordinary mail distribution to the e-Boks solution expressed as person equivalents. The negative values show a reduction in environmental impacts.**

It appears that the reduced contribution to global warming/climate change is most important. When electronic distribution is used instead of distribution by ordinary mail the reduction corresponds to the annual emissions of 190 average Danish citizens. The reduction in the contribution to acidification is of the same magnitude with a reduction similar to that caused by 163 average citizens in a year. In this context, the reduction with respect to nutrification and photochemical ozone creation is of less importance, corresponding to 83 and 52 person equivalents, respectively.

The e-Boks system was divided into four main activities, i.e. storage of documents at KMD A/S, distribution to users, reading, and printing of documents. The relative importance of the four main activities is shown in Figure 2.



**Figure 2. Relative importance of life cycle activities in the e-Boks system with respect to the four environmental impact categories.**

For most impact categories, especially with respect to Global Warming Potential, it is evident that viewing the documents at the users' computer is most important. It has been assumed that the computer is used 3.25 minutes for each document, two minutes is used for the actual viewing and 1.25 minutes is used to log-on to e-Boks. Printing the documents (it is assumed that 15% of all documents are printed in the e-Boks system) also gives a significant contribution, especially to the regional environmental impacts, while e-Boks activities (storage at KMD A/S) plays a small role and distribution via the internet is without practical importance.

## 1.2 Sensitivity analysis

Selected assumptions in the baseline scenario were examined by sensitivity analysis, testing their importance for the overall results. The main findings from this exercise were that

- The time used to view a document is very important. If a document is viewed for 10 minutes instead of 3.25 as assumed in the baseline scenario, the environmental benefits with respect to climate change and consumption of fossil energy almost disappears, although there is still a benefit with respect to the other types of impacts investigated. It follows directly from this that with a shorter viewing or log-on time the benefits from e-Boks will increase significantly.
- Based on questionnaires to the users of e-Boks it has been assumed in the base case scenario that 15% of the documents in e-Boks are printed. Printing a document decreases the benefits of the e-Boks system significantly, between 30 and 40%. The decreased benefit can be attributed to the fact that more paper has to be produced.
- In the base case scenario the calculations were based on average conditions in 2006 with respect to domestic IT equipment. Using more energy efficient IT equipment increases the benefits significantly. Users with (small) laptop computers thus have 17% less impacts on climate change than a user with "average" equipment. Fast internet connections will most probably also show additional benefits for the environment, compared to slow modems.

- Changing the end of life of printouts does not give a homogeneous picture of the consequences for the environment. An increase in incineration will decrease the benefits for climate change, but at the same time there are increased benefits with respect to acidification and consumption of fossil fuels. The outcome probably depends heavily on the availability of renewable resources for both recycling and production of virgin paper, and the findings for this element should therefore be interpreted with great care.

### **1.3 Conclusions**

With the results from the baseline scenario and the sensitivity analysis it is concluded that changing from conventional distribution to the e-Boks system has positive consequences for the environment.

Benefits are observed for all environmental impacts examined, both at the global level (reduced contribution to climate change), the regional level (contribution to e.g. acidification and eutrophication) and with respect to total consumption of energy. It is remarked in this context that potential local impacts on human health or ecosystems have not been addressed to any significant extent.

The benefits (reduction in environmental impacts) are significant, corresponding in the best case (global warming) to the yearly impacts caused by 190 average Danish citizens and at least to the impacts caused by 52 average citizens (smog formation). It is, however, also evident that the use of e-Boks is only a small step towards reaching a political goal of a 20% decrease in emission of climate gases by 2020. This decrease corresponds in crude terms to the emission from one million Danish citizens.

The results are judged to be very robust. A series of sensitivity analysis has been applied in order to investigate worst case with respect to selected elements. Even when worst-case assumptions are applied to these elements there are still benefits from changing to the e-Boks system. The e-Boks system as it is outlined in the system description is thus inherently associated with smaller environmental impacts than the conventional system.

## 2 Sammenfatning

### 2.1 Baggrund

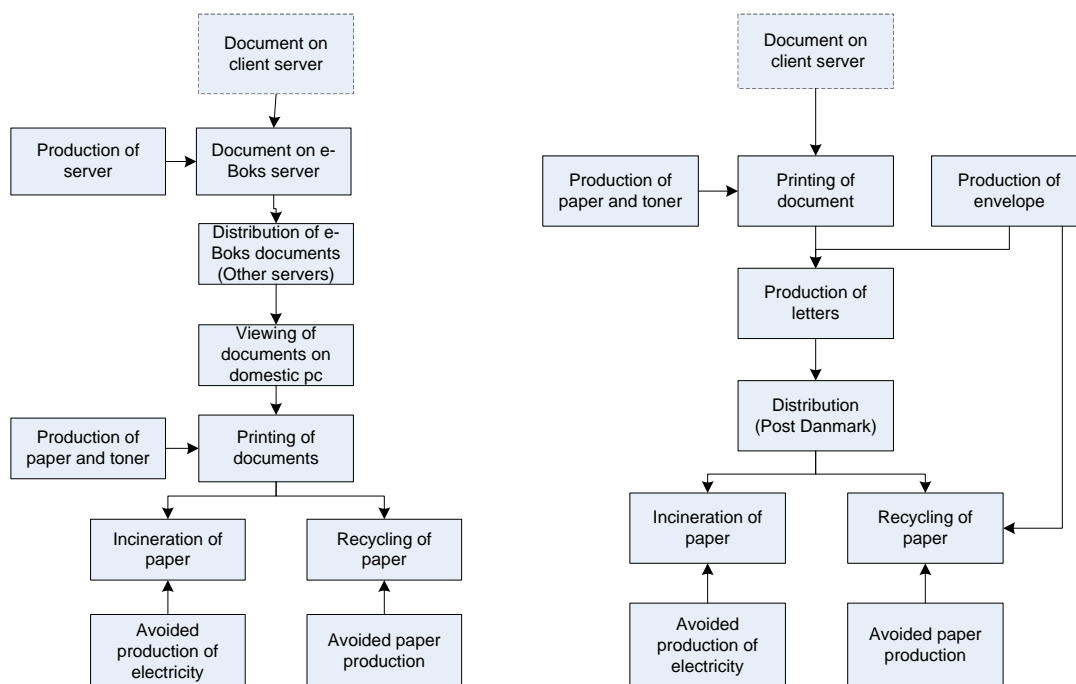
e-Boks er et aktieselskab, der I dag er ejet af PBS A/S og Post Danmark. I 2008 blev der via e-Boks sendt 98,5 millioner elektroniske dokumenter til mere end 1,5 millioner brugere. E-Boks giver desuden brugerne mulighed for at lagre deres egne dokumenter i den personlige postboks, som det er muligt at få adgang til fra en computer med internetadgang.

FORCE Technology har for e-Boks kortlagt de miljømæssige konsekvenser af at distribuere dokumenter som f.eks. kontoudtog, lønsedler og pensionsoversigter elektronisk i stedet for den velkendte måde med papirdokumenter i rudekuverter, der distribueres af Post Danmark. Formålet med denne kortlægning har været at få bekræftet en formodning om, at elektronisk distribution af denne type dokumenter er bedre for miljøet end den almindelige distribution, fordi der både spares papir og brændstoffer til transport. Samtidigt blev det undersøgt, om e-Boks systemet har nogle oversete miljøbelastninger, der eventuelt kan opveje fordelene.

### 2.2 Undersøgelsens omfang

Undersøgelsen har vurderet de miljømæssige konsekvenser af at distribuere 98,5 millioner dokumenter elektronisk i 2008 i stedet for at distribuere dem i form af almindelige breve.

Analysen er lavet som en såkaldt livscyklusvurdering (LCA), der opgør forskelle i miljøpåvirkninger fra vugge til grav, inkl. udvinding af brændsler og råvarer til f.eks. papirproduktion, brugen af computere og bortskaffelse af papir og konvolutter. Figur 1 viser de processer, som indgår i hhv. elektronisk og almindelig distribution af brevene.



Figur 1. De vigtigste elementer og aktiviteter i den elektroniske distribution via e-Boks og distribution med almindelig post.

I denne type LCA kortlægges og beregnes konsekvenserne af at gennemføre en bestemt aktivitet. Et øget elforbrug fører eksempelvis ikke til en øget gennemsnitlig elproduktion, men til at der produceres mere el på et kulfyret kraftværk. Et andet eksempel er, at man ved genanvendelse af papir regner med, at dette vil kunne erstatte nyt avispapir i stedet for papir af sammenlignelig kvalitet. Hvor der har været valgmuligheder i forbindelse med systembeskrivelsen er der til brug i basisscenariet som udgangspunkt foretaget et konservativt valg, der ikke giver et falsk positivt indtryk af fordelene ved e-Boks.

Datagrundlaget, f.eks. i form af vægten af et typisk brev, tiden til at læse et dokument på skærmen, hvor hyppigt der laves en udskrift osv. er etableret på baggrund af information fra centrale aktører som e-Boks, Post Danmark, KMD (der er vært for e-Boks), Konvolut Danmark (producent af konvolutter) og Strålfors (der printer og pakker dokumenter). Disse informationer er parret med oplysninger fra internationalt anerkendte databaser om f.eks. miljøbelastningen ved at producere og genbruge papir, producere elektricitet og andre relevante processer i de to systemer.

Vurderingen omfatter de miljøpåvirkninger, energiforbrug og ressourceforbrug, som typisk opgøres i en livscyklusvurdering:

- Klimaeffekt (også kaldet global opvarmning eller klimapåvirkning)
- Forsuring
- Belastning af vandmiljøet med næringssalte
- Smog-dannelse (fotokemisk ozon)
- Energiforbrug
  - Totalt energiforbrug opgjort i MJ, med mulighed for at skelne mellem fossile energikilder og vandkraft
- Forbrug af fossile energiressourcer samt træ, opgjort i kg eller m<sup>3</sup>
  - Sten- og brunkul, naturgas, olie

Undersøgelsen har ikke vurderet de mulige påvirkninger af mennesker og økosystemer i de to systemer, da de eksisterende metoder og datagrundlag stadig er forholdsvis usikre. Det bemærkes dog, at der ikke forventes at være bidrag til lokale miljø- og sundhedsbelastninger udover de forholdsvis velkendte og velbeskrevne bidrag fra de centrale processer i livsførelsen for dokumenter:

- produktion af papir, f.eks. udledning af miljøfremmede og bio-akkumulerende stoffer til vandmiljøet
- produktion af elektricitet, f.eks. udledning af kviksølv fra kulfyring
- distribution af breve og andre varer, f.eks. udledning af fine og ultrafine partikler fra dieselmotorer
- bortskaffelse af elektronik, f.eks. udledning af tungmetaller

Det bemærkes også, at for de nævnte typer af lokale belastninger har der gennem mange år været iværksat samfundsmæssige initiativer, der fokuserer på at nedbringe belastningen i videst muligt omfang.

## **2.3 Resultater**

### **2.3.1 Hvor stor er fordelene ved e-Boks distribution?**

Beregningerne har været fokuseret på at beskrive de miljømæssige konsekvenser af at distribuere dokumenter som f.eks. kontoudtog, lønsedler og pensionsoversigter elektronisk i stedet for den traditionelle måde som papirdokumenter, der distribueres af Post Danmark. For alle typer af miljøbelastninger er der en klar fordel ved elektronisk distribution af denne

type dokumenter, således som det fremgår af Tabel 1. Negative værdier er således udtryk for en reduktion i miljøbelastningen.

**Tabel 1. Miljømæssige konsekvenser af at distribuere 98.5 millioner dokumenter via e-Boks i stedet for som normale breve.**

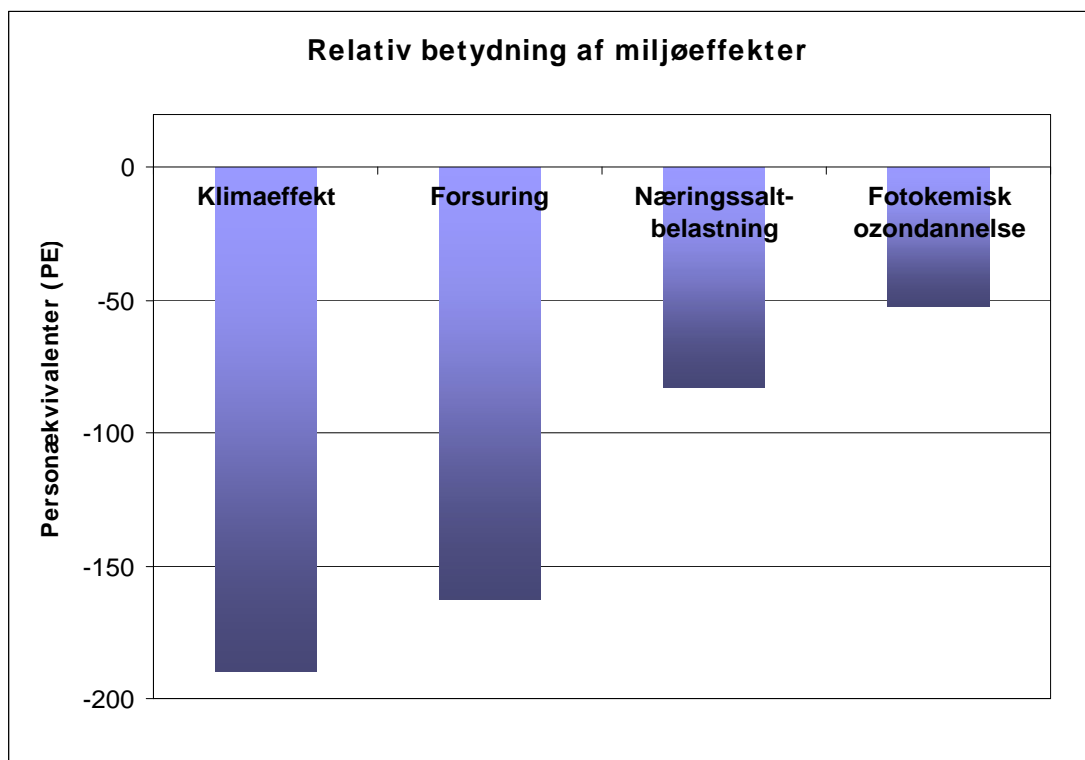
Miljøbelastning	Enhed	Ændring
Klimaeffekt	kg CO <sub>2</sub> -ækv.	-1,652,496
Forsuring	kg SO <sub>2</sub> -ækv.	-16,415
Næringssaltbelastning	kg NO <sub>3</sub> -ækv.	-21,493
Smog-dannelse	kg C <sub>2</sub> H <sub>4</sub> -ækv.	-1,039
Total energiforbrug	MJ	-24,675,481

Foruden en reduktion i de undersøgte miljøbelastninger viser resultaterne også, at der er en markant besparelse på de fossile brændsler (primært kul, olie og gas), mens der er en meget beskedent stigning i brugen af fornybar energi (vandkraft) til produktion af elektricitet. Da den fornybare del af energien udgør mindre end 1% af det samlede energiforbrug, skelnes der i den resterende del af rapporten ikke mellem fornybar og fossil energi.

Tabel 1 viser konsekvenserne i absolutte tal – og i forskellige enheder. Den danske UMIP-metode giver mulighed for at omregne en række miljøbelastninger til en fælles enhed, den såkaldte personækvivalent. En personækvivalent (også kaldet en PE) svarer til en gennemsnitspersons årlige bidrag til en given miljøbelastning. Hver dansker udleder således i gennemsnit omkring 8700 kg CO<sub>2</sub>-ækvivalenter om året som bidrag til klimaforandringer, mens den samme person udleder 101 kg SO<sub>2</sub>-ækvivalenter.

### 2.3.2 Hvad er den største fordel?

Ved at omregne de primære resultater til personækvivalenter (det kaldes også at "normalisere resultaterne") får man således en indikation af, hvilken ændring, der batter mest i det samlede danske miljøbillede. De normaliserede resultater er vist i Figur 2.



**Figur 2. De miljømæssige fordele af e-Boks systemet, omregnet til normaliserede værdier (personækvivalenter).**

Figuren indikerer, at den mest markante fordel er reduktionen i bidraget til drivhuseffekt/klimaforandring, svarende til udledningen fra 190 gennemsnitsdanskere. Bidraget til forsuring reduceres næsten lige så meget, svarende til 163 personækvivalenter. Den positive effekt med hensyn til næringssaltbelastning og fotokemisk ozondannelse er mindre, men stadig signifikant.

UMIP-metoden giver ikke mulighed for på samme måde at normalisere resultaterne for energiforbrug og –besparelser. Ud fra Energistatistik 2007 fra Energistyrelsen kan det dog beregnes, at en gennemsnitsdansker bruger cirka 159.000 MJ energi om året. Besparelsen på godt 24 millioner MJ ved at distribuere gennem e-Boks svarer således til energiforbruget for 155 gennemsnitsdanskere. Denne besparelse kan også udtrykkes i såkaldte olie-ækvivalenter, der er den enhed som OECD anvender til at sammenfatte målinger af energiforbrug. Besparelsen ved at bruge e-Boks er ca. 590.000 kg olieækvivalenter, der ifølge beregningerne fordeler sig på følgende måde på forskellige fossile brændsler:

	Kg	MJ
Råolie	-287,670	-12,309,350
Stenkul	43,210	1,139,618
Brunkul	-113,577	-1,303,812
Naturgas	-254,147	-10,941,401
Uran	-1.399	-1,261,457

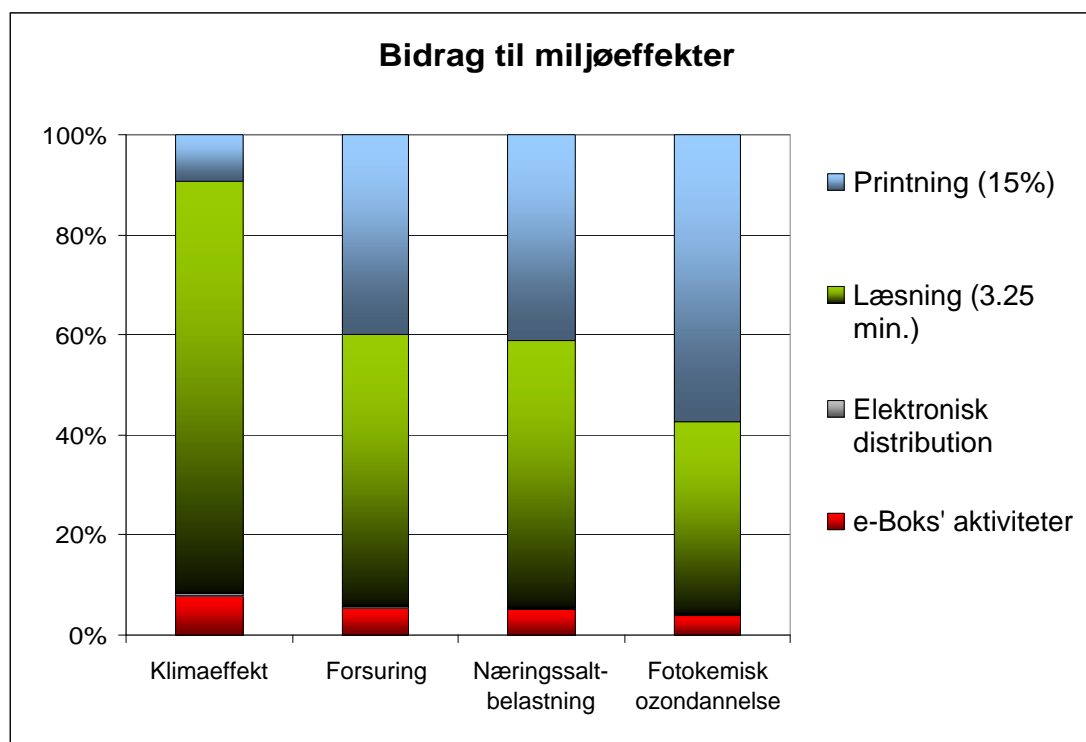
Besparelserne ligger primært på råolie, der anvendes til produktion af benzin, diesel, fyringsolie og plastmaterialer og på naturgas, der anvendes til produktion af elektricitet, varme og diverse materialer. Ændringerne for stenkul, brunkul og uran afspejler, at et mindre papirforbrug i e-Boks systemet på den ene side medfører en sparet el-produktion i lande, hvor uran og brunkul er væsentlige energikilder, mens der skal produceres ekstra elektricitet på moderne danske kulkraftværker, fordi der ikke er så megen energi at hente fra forbrænding af papiraffald.

### 2.3.3 Hvor ligger de væsentligste miljøbelastninger i e-Boks systemet?

I undersøgelsen er e-Boks systemet delt op i fire hovedaktiviteter:

- Aktiviteter hos e-Boks (primært lagring og visning af dokumenter)
- Elektronisk distribution via internetudbydere
- Læsning af dokumenter hos brugeren
- Printning af dokumenter (primært produktion og bortskaffelse af papir)

Figur 3 viser, hvilke aktiviteter, der har den største belastning:



Figur 3. Relativt bidrag til forskellige miljøbelastninger fra de fire hovedaktiviteter i e-Boks.

Figuren illustrerer klart, at "Læsning" af dokumenterne giver det største bidrag med hensyn til klimaeffekt, mens bidraget til de øvrige miljøbelastninger er mere ligeligt fordelt mellem Læsning og Printning. I det samlede billede spiller aktiviteterne hos e-Boks en meget lille rolle og den elektroniske distribution via en internetudbyder er uden praktisk betydning.

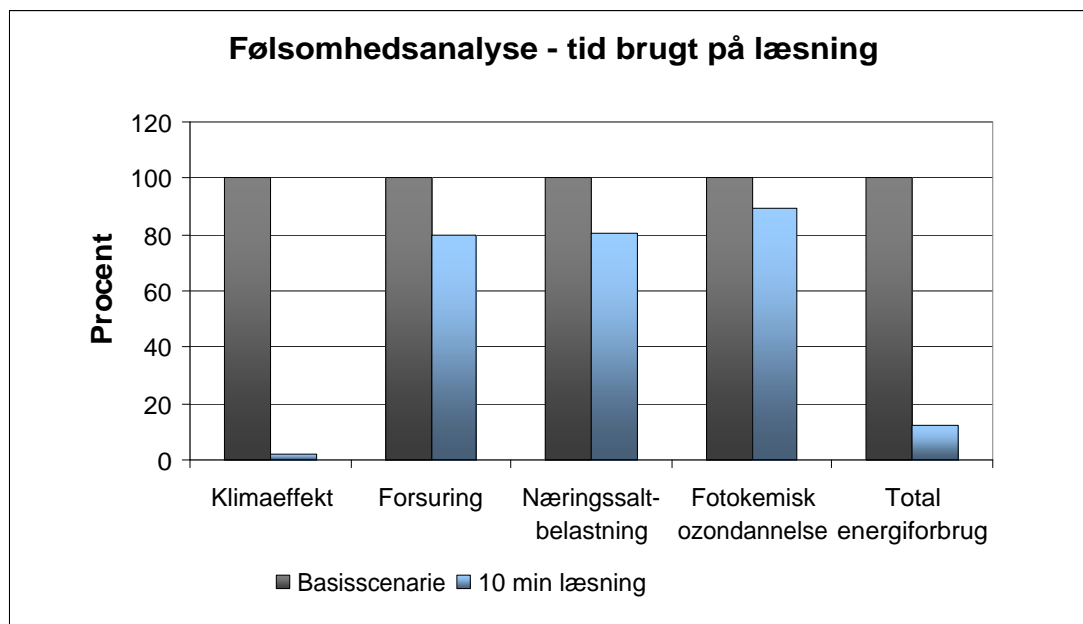
## 2.4 Resultaterne er robuste

Det er altså den enkelte bruger af e-Boks, der langt hen ad vejen kan bestemme, hvor stor en miljøbelastning, der er knyttet til at modtage dokumenter via e-Boks. I en følsomhedsanalyse blev betydningen af forskellige antagelser derfor analyseret for at være sikker på, at resultater og konklusioner er robuste, også for brugere der har andre vaner omkring brugen af e-Boks end den "gennemsnitsbruger", der er forudsat i det grundlæggende scenarie.

### 2.4.1 Tid brugt på læsning

Det er som udgangspunkt antaget, at en bruger anvender sin pc i tre minutter og 15 sekunder for hvert dokument, der modtages i e-Boks. To minutter bruges til at læse

dokumentet, mens der bruges 1.25 min på at logge på e-Boks. De to minutter er et målt gennemsnit for e-Boks dokumenter, mens tiden til log-on er baseret på, at der i gennemsnit åbnes 1,6 dokumenter hver gang der logges på e-Boks. Nogle brugere kan dog tænkes at anvende noget længere tid, enten fordi de har en langsom internetforbindelse eller fordi de gennemgår dokumenterne minutløst. Der blev derfor gennemført beregninger, hvor det blev antaget at den samlede tid til at læse et dokument var 10 minutter i stedet for de godt tre minutter. Resultaterne af denne analyse fremgår af Figur 4.



**Figur 4. Relativ miljøbelastning ved et tidsforbrug til læsning på 10 minutter i stedet for 3,25 minutter som i basisscenariet. Tal under 100% indikerer generelt, at fordelene ved e-Boks bliver mindre.**

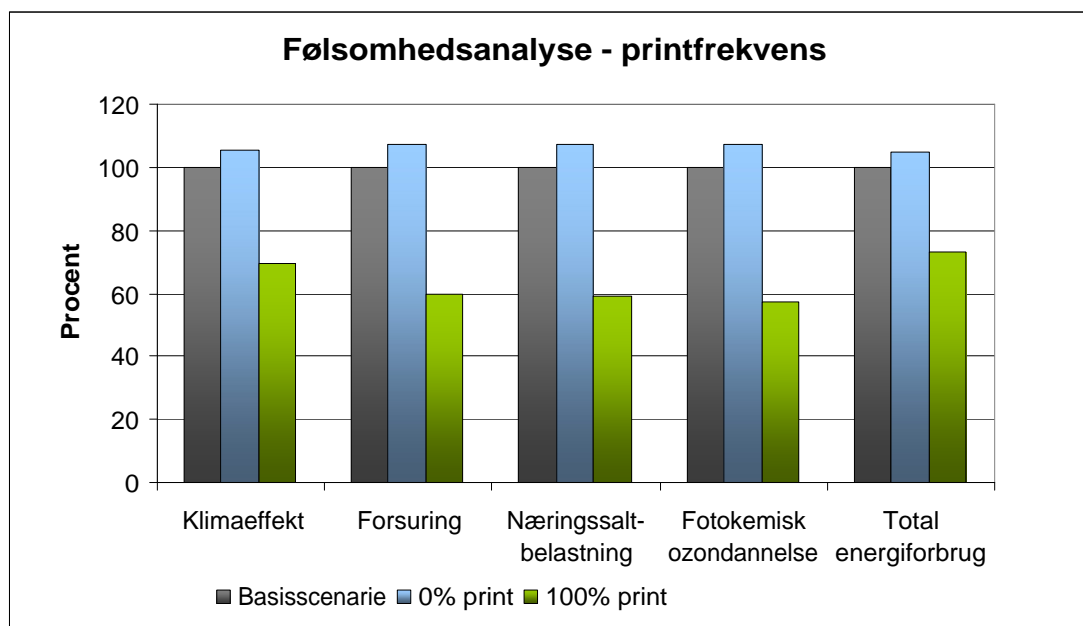
Hvis en bruger anvender væsentligt længere tid – i dette eksempel 10 minutter – på at læse et dokument i e-Boks, forsvinder en stor del af fordelene ved e-Boks, specielt med hensyn til bidraget til klimaforandringer og totalforbruget af energi. For begge effekters vedkommende skyldes den mindre fordel, at der bruges mere elektricitet til pc, skærm og andet IT udstyr. Effekten er ikke så stor for de andre miljøbelastningers vedkommende, hvilket skyldes at disse ikke er relateret til energiforbrug alene, men også til forbrug af papir til udskrivning af dokumenter.

Det understreges, at denne følsomhedsanalyse primært viser effekten for den enkelte bruger med et stort tidsforbrug. Gennemsnitstiden på godt tre minutter, som anvendes i basisscenariet, anses for at være et meget realistisk estimat, der afspejler daglig praksis.

#### 2.4.2 Hvor ofte skrives et e-Boks dokument ud?

En undersøgelse blandt brugere af e-Boks viste, at omkring 15% af de dokumenter, der åbnes, også skrives ud. I praksis er det ikke alle dokumenter, der åbnes, og en udskriftshyppighed på 15% giver derfor et konservativt estimat.

For at belyse dette nærmere, blev der lavet beregninger af belastningen, hvis alle dokumenter skrives ud, og hvis ingen skrives ud. Ingen af disse scenarier er realistiske, men resultaterne giver en god indikation af, hvor stor en del af fordelene, der forsvinder hvis der printes ud, og hvor stor en ekstra gevinst der opnås, hvis et dokument ikke skrives ud. Resultaterne fremgår af Figur 5.



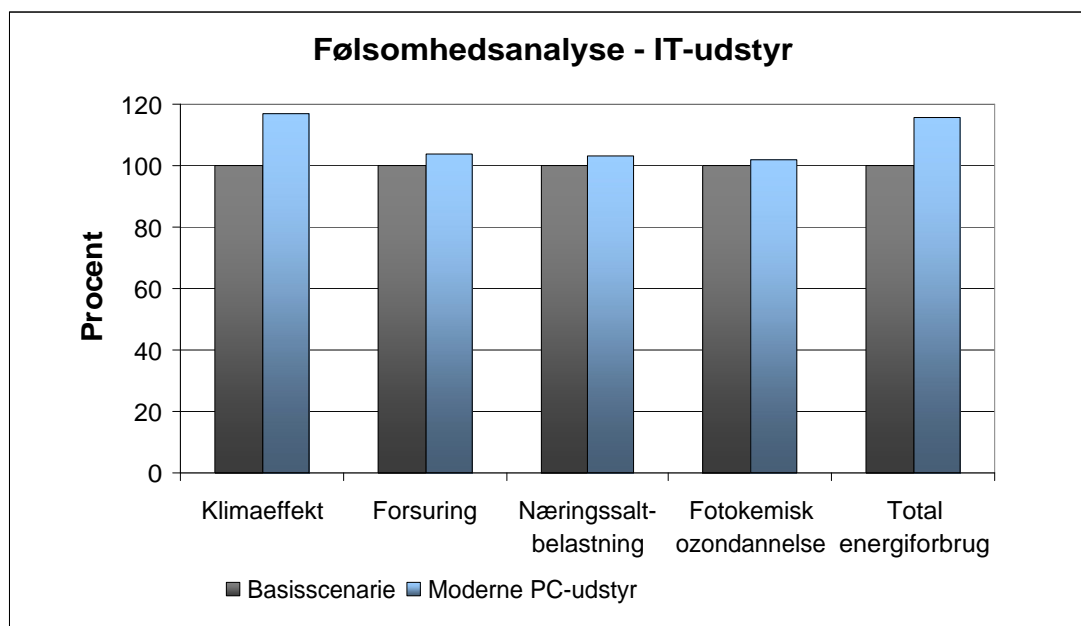
**Figur 5. Relativ miljøbelastning ved udskrivning af ingen eller alle dokumenter i forhold til basisscenariet med 15% udprintning. Tal under 100% indikerer generelt, at fordelene ved e-Boks bliver mindre; over 100% indikerer at fordelene øges.**

Resultaterne viser, at 30-40% af fordelene ved e-Boks forsvinder, når et dokument skrives ud. Årsagen til dette er, at der sker en forøgelse af papirforbruget og de miljøbelastninger, der er knyttet til papirproduktion. Der er dog stadig en signifikant fordel ved e-Boks systemet, der for størstedelens vedkommende kan henføres til, at der ikke skal produceres og sendes en konvolut med dokumentet i.

Analysen viser også, at der kan opnås en ekstra fordel på 5-7% i det samlede resultat for alle typer af miljøbelastning, hvis ingen dokumenter skrives ud.

### 2.4.3 Brug af moderne IT udstyr

I basisscenariet er brugt et veldokumenteret gennemsnit af hjemmenes IT udstyr i 2006 som forudsætning for beregningerne. Denne antagelse er ikke nødvendigvis særlig repræsentativ for brugere med et mere moderne udstyr, f.eks. bærbare computere, der har et relativt lavt strømforbrug. Der blev derfor gennemført en følsomhedsanalyse, hvor strømforbruget blev nedsat med 60 Watt per time, svarende til forskellen mellem en pc med skærm, der bruger 100 W og en bærbar, der bruger 40 W. Resultaterne fremgår af Figur 6.



**Figur 6. Miljøbelastning ved brug af bærbare computere i forhold til basisscenariet. Værdier højere end 100% indikerer en større fordel i forhold til basisscenariet.**

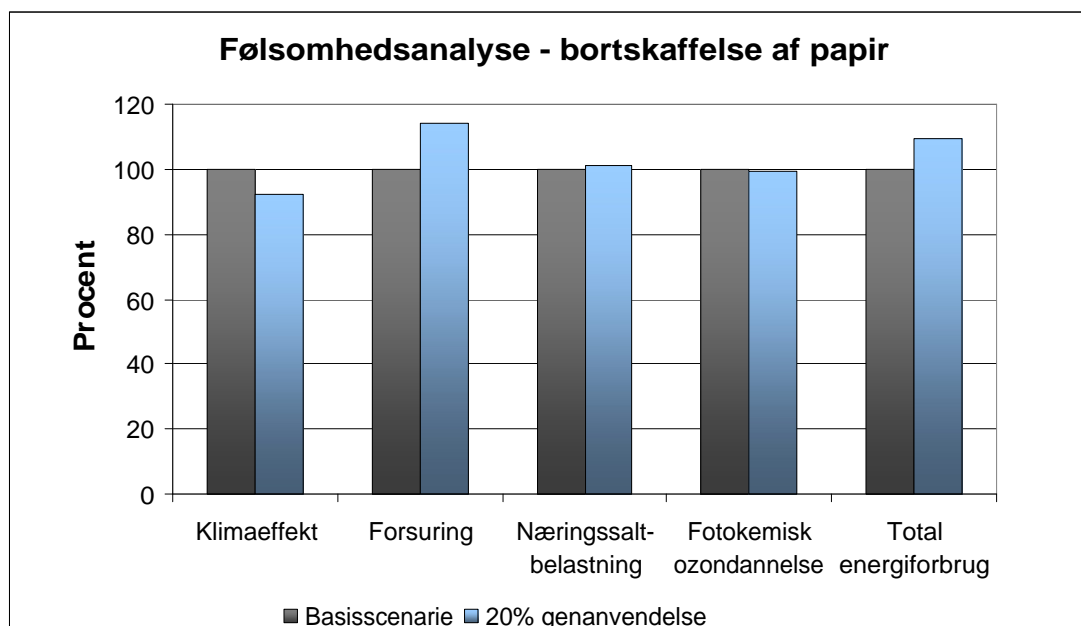
Resultaterne viser, at fordelene ved e-Boks systemet i høj grad er relateret til energieffektiviteten af IT-udstyret. Der er en signifikant fordel ved at bruge bærbare computere frem for stationære, mest udtalt i forhold til bidraget til klimaeffekten (17% forbedring) og til forbruget fossil energi (15%).

Det bemærkes, at den fremtidige udvikling på IT-området ikke nødvendigvis går ensartet i retning af lavere energiforbrug eller højere energieffektivitet. Bærbare computere, især små apparater, må forventes at blive meget mere almindelige, men der vil sikkert også ske en udvikling for stationære computere i retning af en mere kraftfuld ydelse, der opnås på bekostning af et øget energiforbrug. Samlet set vil udviklingen i den nærmeste fremtid dog ikke kunne rokke ved den vurdering, at læsning af e-Boks dokumenter giver det største bidrag til det samlede billede.

#### 2.4.4 Behandling af papiraffald

I beregningerne er der som udgangspunkt gået ud fra, at e-Boks dokumenter og kuverter behandles som gennemsnittet af andet papir- og papaffald i Danmark i 2008, nemlig at 60% genanvendes og 40% forbrændes med energigenvinding.

Da den type dokumenter, der typisk distribueres via e-Boks, ofte indeholder personlig, økonomisk information, vil en del personer sikkert sørge for, at dokumenterne forbrændes, fordi risikoen for at uvedkommende skal få adgang til informationen derved minimeres. Vi har derfor undersøgt konsekvenserne, hvis kun 20% af papir og kuverter genanvendes, mens de resterende 80% forbrændes med energigenvinding. Resultaterne af dette fremgår af Figur 7.



**Figur 7. Miljøbelastning ved en øget forbrænding af papir (80%) i forhold til basisscenariet, hvor 40% forbrændes med energigenvinding. Værdier højere end 100% indikerer en større fordel i forhold til basisscenariet.**

Beregningerne viser, at fordelene ved at skifte til e-Boks bliver mindre med hensyn til klimaeffekt, når andelen af papir, der forbrændes, bliver øget. Til gengæld er der en større fordel med hensyn til både energiforbrug og forsuring, mens der kun sker ubetydelige ændringer med hensyn til næringssaltbelastning og fotokemisk ozondannelse. Det understreges dog, at der i begge scenarier stadig er tale om en konsistent fordel for miljøet ved elektronisk distribution frem for konventionel distribution.

Den primære årsag til de beskrevne ændringer i resultaterne er, at der anvendes mest papir ved konventionel distribution af dokumenter. Når en større mængde af dette forbrændes, fortrænges anden energi, der ellers ville være blevet produceret med kul-baseret teknologi. Samtidigt er der mindre papir til genanvendelse, og det er derfor nødvendigt at producere mere virgint papir.

## 2.5 Konklusioner

I undersøgelsen er de miljømæssige konsekvenser ved at distribuere automatisk genererede dokumenter elektronisk i e-Boks systemet frem for med almindelig post beregnet. Det bemærkes, at resultaterne ikke er repræsentative for andre typer af dokumenter, f.eks. personlige breve, der både har et andet livsforløb og som opfylder andre funktioner.

Resultaterne peger entydigt på, at der er en klar fordel ved elektronisk distribution, idet der er en positiv effekt for alle typer af miljøbelastninger, der er undersøgt, både globalt (nedsat bidrag til klimaforandringer), regionalt (f.eks. bidrag til forsuring og næringssaltbelastning), og med hensyn til det totale forbrug af energi. Det bemærkes dog, at potentielle påvirkninger af menneskers sundhed og lokale økosystemer ikke er indgået i beregningerne.

Hvor relevant er det tilstræbt at vælge konservative antagelser, der ikke favoriserer e-Boks systemet. Dette understøtter vurderingen af, at konklusionerne er meget entydige, og indikerer samtidigt, at fordelene i absolutte tal sandsynligvis er højere end angivet i rapporten.

Målt i absolutte tal svarer de miljømæssige gevinster til udledningerne fra ca. 160-190 gennemsnitsdanskere (med hensyn til klimaeffekt og forsuring) og til noget mindre med hensyn til næringssaltbelastning og dannelse af fotokemisk ozon. De fordele, som et skift til

distribution via e-Boks giver, er dermed et lille skridt på vejen mod de overordnede reduktionsmål på 20% for udledningen af klimagasser i 2020.

Med de givne begrænsninger må resultaterne anses for at være meget robuste. Dette understøttes af en række følsomhedsanalyser, hvor der selv med worst-case betragtninger på udvalgte områder er en klar miljømæssig fordel ved e-Boks systemet i forhold til konventionel distribution af automatisk genererede dokumenter.

### **3 Introduction**

Establishing digital solutions is becoming a common approach to handle many everyday activities. Exchange of information can be done in a fast and reliable way, and both private companies like banks and public institutions like SKAT (the tax authority) have developed advanced solutions which are widely used.

The Danish company e-Boks offers a personal and safe electronic post box, where the users can receive important documents (annual statements from banks and insurance companies, bank accounts statements, payslips, etc.) free of charge. e-Boks also gives its users the possibility of uploading and storing their private documents. The core service of e-Boks is thus an alternative to the traditional way of distributing information on paper.

e-Boks is a public limited company and was until March 2009 owned by three large companies with national leadership within areas like IT solutions for the public sector (KMD A/S), distribution of mail (PostDanmark A/S) and electronic payments (PBS A/S). However, KMD sold their shares to PostDanmark and PBS in March 2009. Today, e-Boks has more than 1.5 million users who each year receive 98.5 million documents via the Internet.

Compared to the conventional solution, the digital solution is believed to be beneficial for the environment because of a reduced need for paper and fuel for transportation. However, using e-Boks may have some "hidden" or unknown consequences for the environment, e.g. through the use of IT equipment and electricity, and e-Boks and one of its major clients, Danske Bank, has therefore asked FORCE Technology to quantify the actual consequences for the environment caused by distributing 98.5 million documents through the e-Boks system instead of by traditional letters.

### **4 Goal of the study**

The goal of the study is to quantify the environmental consequences of using e-Boks as an alternative to conventional distribution of documents by ordinary mail. The quantification is primarily done at the overall level, using the 2008 distribution of 98.5 million documents as a basis for the calculations. If desired, the information can easily be scaled to a single "average" e-Boks document or to the impacts caused by the average user in Denmark. This has, however, not been done as an element of this report.

An important target group for the study is existing and potential users of e-Boks who can use the knowledge to decide whether or not to use e-Boks and – if already a user – how to use the service with the least environmental impact. An equally important target group is e-Boks and its owners who will learn the most demanding activities from an environmental point of view and use this knowledge to reduce the impacts. An additional possibility for the owners is to use the results in marketing of e-Boks services. Finally, the study will provide a general insight to the public about "digitalisation of society", being one of the first studies of its kind.

### **5 Scope of the study**

The study is a Life Cycle Assessment (LCA) examining the environmental consequences of changing from conventional distribution by ordinary mail to electronic distribution via the Internet.

## **5.1 Functional unit**

The functional unit is "the distribution of 98.5 million documents in 2008 using the e-Boks concept".

The documents distributed in the e-Boks system are to a very large extent generated automatically from information stored in the client's system, e.g. monthly bank account statements, payslips and annual statements from insurance companies. These documents would otherwise have been produced physically and distributed by ordinary mail in window envelopes.

It is a basic assumption of the study that both senders and receivers of the documents find electronic distribution to be a satisfactory solution. The main part of e-Boks users have actively chosen to receive selected documents through e-Boks, e.g. by sending a confirmation message to the company or institution suggesting to use e-Boks. It is, however, remarked that the solution is forced upon a few users who would rather have the documents sent by ordinary mail, e.g. because they do not have their own computer.

## **5.2 LCA approach**

### **5.2.1 Consequential LCA**

There are two basic approaches to LCA. In "attributional" (or accounting) LCA, the environmental impacts of a product or a system are calculated as they appear to be. In "consequential" (or effect-oriented) LCA the consequences of a given choice are modelled and calculated.

According to the ISO LCA standards, allocation should be avoided wherever possible. Using the consequential LCA-approach reduces the need for allocation, making use of system expansion and the avoided burden approach to a very large extent. However, allocation can be used when a precise identification of which processes are affected and to what extent is judged to be very demanding in terms of resources.

In Denmark, consequential LCA is recommended when examining systems like those addressed in the present study. It is therefore also the general approach used in the study. In principle, only the differences between the two systems need to be addressed in a consequential LCA. As the two systems are very different in nature, a fairly detailed LCA has been made of each system, allowing for a direct comparison of the activities within the system boundaries.

In a few cases, allocation could not be avoided. One example is the allocation of energy consumption at KMD, the host for e-Boks, between e-Boks and other activities according to the amount and capacity of the servers installed.

### **5.2.2 Impact assessment**

Several methods for calculations of the environmental impacts are available. In this study, the impact assessment will primarily be made using the Danish EDIP methodology, which is internationally recognised (Hauschild and Wenzel, 1998). Compared to the full methodology, some simplifications have been made. Most notably, the impact categories addressed will be limited to the following global and regional impacts:

- Global Warming Potential (GWP) (using the most recent update of the CML 2001 method). Global Warming is also referred to as the greenhouse effect or climate change, but the calculation method is the same in all cases, addressing the effect of increasing temperature in the lower atmosphere.
- Acidification Potential (AP). Acidification is a regional effect caused primarily by emission of sulfur dioxide and nitrogen oxides, which may lead to e.g. forest die-back and clear lakes without aquatic life.
- Nutrification Potential (also called Eutrophication Potential, EP, or nutrient enrichment potential) reflects primarily the regional emission of nutrients (nitrogen and phosphorous) to the aquatic environment where they may cause depletion of oxygen in the bottom layers and – as a consequence – lifeless environments.
- Photochemical Ozone Creation Potential (POCP). Formation of ground level ozone ("smog") is an important threat at the regional scale. At high concentrations it is hazardous to human health but already at lower concentrations it causes damage to vegetation.
- Consumption of energy (measured in MJ), distinguishing if relevant between
  - Renewable (primarily hydropower) and
  - Fossil energy
- Consumption of energy resources, focusing on natural gas, coal and crude oil (in kg)

Local environmental impacts like human toxicity and ecotoxicity are only addressed to a very minor extent as is the case for assessment of waste. The local environmental impacts are not included, because they can only be managed with a relatively high degree of uncertainty. The emissions of relevant substances are in many cases determined with large uncertainty and/or in an inconsistent manner, and the potential effects (the so-called characterisation factors) have only been established for a limited number of substances.

It is thus not possible to make a precise quantification of the impacts from activities like generation of electricity (e.g. through emissions of mercury), distribution by diesel cars (e.g. through emission of fine and ultra-fine particles), disposal of electronics (emission of heavy metals) and production of paper (e.g. emission of bio-accumulating substances). It is, however, noted that the cause-effect chains are well-known and considerable efforts have been devoted to a reduction of the impacts through focused initiatives on the societal level.

The CML 2001 method is preferred to the EDIP method to calculate results for Global Warming Potential, the reason being that the CML method is fully up to date with respect to IPCC characterisation factors for single substances.

### 5.2.3 Calculation tool and data sources

The LCA software tool GaBi 4 from PE International was used for the calculations.

For most unit processes like production and recycling of paper, the ecoinvent 2.0 database as available in GaBi 4 was used (Frischknecht et al., 2007). For production of marginal electricity in Denmark, results from an LCA made by the major Danish energy companies as available in the GaBi/EDIP database was used.

Process-specific inventory data, e.g. relating to paper and energy consumption, were established using information from representative companies. For consumption of electricity in private households information was derived from publications from the Danish Energy Agency. A detailed description of the data and how they were derived can be found in the sections on system boundaries.

### **5.3 System boundaries – general considerations**

Using the consequential approach implies that the processes actually affected are considered, identifying the marginal processes where possible. It is outside the scope of this report to go into more detail with respect to the theoretical aspects behind the choice of LCA approach. These are well described in e.g. Ekvall and Weidema (2004) and Weidema (2003) and the interested reader is referred to these reports. The more practical implications, e.g. which choices have been made – and why – are described in some detail for relevant activities in the system descriptions in the subsequent sections.

## 6 Inventory analysis

The study addresses the total amount of documents stored in e-Boks in 2008, 98,500,000. Most inventory calculations have been made by down-scaling (e.g. allocating some of the electricity consumed at KMD to e-Boks activities) or up-scaling (e.g. by estimating the electricity consumed for viewing an average document and multiply this with the total number of documents). The general approach has been to identify the consequences of changing from conventional to digital distribution and calculate the derived effects. The basic data and their treatment are described in detail for each activity.

However, the following sections describe some of the main assumptions used in the study, together with the physical (weight and size) characteristics of the available options.

### 6.1 The average document

Post Danmark assumes in its calculations that the average letter consists of two sheets of paper, size A4 (of different paper qualities) and one envelope, size C5. The weight of these components is 17.66 gram, excluding losses during production processes Søren Boas, pers. comm., April 2009).

The documents distributed by e-Boks clients, however, vary by both the number of sheets, the paper quality used, and the size of the envelope. The average number of sheets in letters from PBS, the largest single customer with a share of 47% of the documents, is thus 1.5 and an envelope size M55 is used. The average number of sheets in documents from Danske Bank (25% of all documents) is 2.2 and an envelope size M5 is used. From SDC, accounting for 6% of the documents, the average number of sheets is 1.8. Assuming that the remaining 19% consist of two sheets the average number of sheets in an e-Boks document is 1.8.

The paper quality used for the documents is either 70 g/m<sup>2</sup> as used by e.g. Danske Bank and PBS (for 80% of the documents) or 80 g/m<sup>2</sup> which is the quality used for the remaining 20% of the documents from PBS. The weights are 4.4 and 5.0 g/sheet, respectively. Paper of better quality (90 g/m<sup>2</sup>) is assumed not to be used to any significant extent in documents of the e-Boks type. Assuming that the rest of e-Boks clients use the 70 g/m<sup>2</sup> quality, the average weight of a sheet can be calculated to 4.43 g. The average document thus weighs 7.97 g.

Based on the above information on 80% of the documents, we have assumed that the average number of sheets is 1.8 sheets and that equal amounts of envelopes size M5 and M65 are used. With a paper weight of 6.62 and 4.92 g, respectively for the two sizes, the average weight of paper in an envelope is 5.77 g, including glue and toner. To this weight is added the weight of an acetate window, 0.2 g, giving a total weight of the average envelope of 5.97 g.

With the choices outlined above the weight of the average document in its envelope can be calculated to 13.94 g. The number of documents stored in e-Boks in 2008 was 98,500,000, and these documents would weigh about 1370 tons if they should be distributed by ordinary mail in window envelopes. It is noticed that the avoided production of paper is a few percent larger, since there are losses of paper in various processes, most notably in the production of envelopes. The calculations include these losses as described in more detail in other sections.

The average size of an e-Boks document is 36 KB. About half of the users receive an e-mail (size 3 KB) when there is a new document, and one document transmitted to the user is therefore assumed to have a size of 38 KB.

## **6.2 Common activities for e-Boks and conventional distribution**

Some important activities are common to both systems examined, i.e. the life cycle of paper (production and end-of-life) and production and consumption of electricity.

### **6.2.1 Paper production**

We assume that the paper used for the documents is "normal" office paper (woodfree, uncoated fine paper). Data from the ecoinvent database are used in the calculations, reflecting average European conditions with 50% being produced at integrated mills and 50% being produced at non-integrated mills (Hischier, 2007). It is mentioned that the inventory regards production of virgin paper and that it also includes forestry.

The paper is assumed to be produced in Sweden or Finland and transported 1230 km by ship and 150 km to Denmark by truck, irrespective of where in Denmark the paper is used and whether it is used for industrial or domestic printing.

### **6.2.2 End-of-life of paper**

At some point in time the paper copies of bank account statements, payslips etc. shall be disposed of, irrespective of whether they have been produced by the sender (in the conventional system) or the receiver (in the e-Boks system). Some people will discard their documents shortly after receiving or printing them, while others will store their documents for decades.

In many European countries, including Denmark, it is not allowed to landfill waste which can be utilized in recycling or energy recovery. Two options for end-of-life treatment are thus available today and they are also expected to exist and be used for several decades. One option is to recycle the paper, producing e.g. writing paper, newsprint or carton/cardboard, and the other option is to incinerate the paper with recovery of the inherent energy

Denmark has for many years been a frontrunner in optimising the environmental benefits in waste incineration, but the general recommendation has been to recycle paper whenever feasible, following the overall waste hierarchy as outlined in the EU waste directive.

According to the Danish waste strategy for 2005-2008, 59% of the paper waste from the households was collected for recycling in 2001 and the target for 2008 was to maintain the 60% recycling of cardboard and paper (Regeringen, 2003). Therefore we have assumed in the base case scenario that 40% will be incinerated with energy recovery and 60% will be recycled.

#### **Incineration with energy recovery**

The inherent energy in paper is utilised when paper waste is incinerated in Denmark. In most Danish waste incineration plants both electricity and heat is produced in varying amounts, substituting energy produced by using conventional energy sources of fossil origin. According to Schmidt and Strömberg (2006) the heat substituted will primarily be waste heat and thus we do not include any credit for the heat production.

The electricity production is assumed to substitute electricity produced at modern coal-fired combined heat and power plants (CHP) (Schmidt and Strömberg, 2006; C.F. Nielsen, energinet.dk, pers. comm. 2008). Data for the incineration of the paper has been taken from the ecoinvent database, assuming a calorific value of 14.6 MJ/kg and that 0.17 MJ electricity is produced per MJ paper incinerated, cf. Schmidt and Strömberg (2006). It is remarked that the calorific value may be slightly overestimated since the paper also contains additives like

kaolin with heat value. This is a conservative estimate for e-Boks, because much more paper is used for conventional distribution.

Data for the coal-fired plant have been developed as an element in the EDIP methodology, based on 2001-information from the largest energy producers in Denmark, and integrated in the GaBi-EDIP-database. The original process has been modified slightly, assuming in line with the recommendations in Schmidt and Strömberg (2006) that 0.32 MJ electricity is produced per MJ coal being used as fuel.

### **Recycling of paper**

The output of the paper recycling process can be writing paper, newsprint, de-inked pulp or carton/cardboard, depending on the quality of the collected fraction, geographical conditions and the market demand.

Documents are collected from private households together with old newspapers and printed matter, which constitutes a much larger fraction of the collected paper than the documents. The collected paper may be further sorted in order to increase the value, but it is most probably sold in bulk.

About 10-15% of the collected paper is recycled in Denmark, the output being different cardboard qualities, tissue paper and wood-free paper. The remaining 85-90% is exported, primarily to Sweden and Germany where it is used for production of newsprint. It is, however, remarked that Germany has a large re-export to countries like Austria and the Netherlands, and some of the paper may eventually end as a raw material in China or other Asian countries, where the demand for paper fibres is increasing fast.

It has been outside the scope of the present study to establish a precise model for recycling of waste paper from Danish households, a main reason being that the ecoinvent database does not contain data for relevant Danish paper recycling processes, but only for the dominant processes in Switzerland and in the EU.

Therefore, a simplified model has been established, assuming that all the documents collected together with newsprint and printed matter are recycled into newsprint in either Sweden or Germany. In 2008, 54% of the Danish waste paper from newsprint etc. was exported to Sweden and 38% to Germany according to statistics from Eurostat's External Trade Database (COMEXT). The recycling processes are somewhat different in the two countries, especially with respect to the energy sources used, but we have chosen to use an average European process to account for recycling in both countries, i.e. the ecoinvent process "RER: paper, newsprint, DIP containing, at plant" (DIP = De-inked Pulp). The output from the process is newsprint, which is assumed to substitute newsprint made from virgin resources as reflected in the ecoinvent process "RER: paper, newsprint, 0% DIP, at plant", which is an average process, based on European production statistics (Hischier, 2007). The approach is judged to be in line with the modelling of paper recycling in ecoinvent.

The waste paper is transported to the recycling facilities by truck. An average distance of 500 km has been assumed for transport to Sweden and Germany.

### **Sensitivity analysis**

Since documents like bank account statements are confidential or very personal information, the owners may be more susceptible to send the documents to incineration (together with other household waste) than to send the paper to recycling. We therefore apply a sensitivity analysis where we assume that 80% of the paper is incinerated with energy recovery and 20% is recycled.

### 6.2.3 Production and consumption of electricity

In line with the consequential LCA approach used in the study, the marginally produced electricity is used in the calculations. The marginal electricity comes from the plants that actually increase their production when there is an increased demand, e.g. when a computer is turned on.

As explained above, coal-fired power plants have for some years been modelled as the marginal electricity source, and it is also this assumption which is used in the study for all consumption of electricity directly related to the performance of the two systems. The electricity consumed for production of raw materials like paper and toner is, however, accounted for in the same way as in the original database inventories from ecoinvent, i.e. with European average electricity.

However, the ambitious reduction targets announced by the Danish government and the CO<sub>2</sub>-quota system in the EU raise some additional issues to be considered.

The reduction targets shall be reached through several initiatives. One is to increase the wind power capacity in Denmark, and the largest energy provider in Denmark, DONG Energy, has therefore initiated new projects like Horns Rev 2, which is a large off-shore wind farm. This is done in close collaboration with major Danish electricity consumers like Novo Nordisk, Novozymes and KMD. DONG Energy helps the companies save energy and in return, the companies invest the saved costs in wind turbines and agree to pay an additional price for the wind-based electricity. Besides the possible financial benefits, the main motivation for the companies to do so is probably that they believe that their investments will actually increase the amount of sustainable electricity being produced in Denmark and that their commitment in this can be used for external communication, e.g. in green accounts.

It is, however, an open question today if the investment and the additional price paid have any effect in practice. It is thus argued from several sides that the wind mill park would be established independent of external funding simply because it is not possible to reach the Danish reduction targets without this initiative. A further argument is that reductions which are additional to the Danish targets will just result in CO<sub>2</sub>-quotas becoming available for sale at the quota exchange, allowing other energy producers in the EU to emit the CO<sub>2</sub>.

Using a similar line of argumentation it can also be argued that the extra electricity used in the e-Boks system (and other activities) is CO<sub>2</sub>-neutral. The amount of quotas is fixed and it can thus not be increased as a consequence of an additional demand for electricity. Therefore, the extra demand must be met by using CO<sub>2</sub>-neutral sources like wind and biomass.

Assuming in the study that the extra demand for electricity related to the e-Boks system is met by coal-fired power plants is thus a conservative approach. In the utmost – and perhaps theoretical - consequence, the e-Boks system becomes almost without impacts on the environment. The electricity consumed in various activities will in this case generated from wind or biomass with very low impacts, and the main impacts in the e-Boks system will therefore come from the small amount of paper being consumed.

#### Sensitivity analysis

We have chosen neither to assume in the base case that the consumed electricity is “green”, nor to examine the option in a sensitivity analysis. Although the scenario outlined may prove to be close to real-life conditions in a near future, its inclusion in the present study can be seen as an effort to greenwash the e-Boks system. The chosen approach, i.e. to account for all electricity as “black”, must be regarded as conservative and the results can therefore be interpreted with large confidence.

### 6.3 The e-Boks system

In the e-Boks system there is a limited flow of physical substances, but a significant consumption of energy for storage, distribution and reading of electronic documents. The following sections outline how relevant elements and activities are included in the calculations and it is also explained to some extent why other activities have been excluded.

The processes in the e-Boks system are outlined in Figure 3.

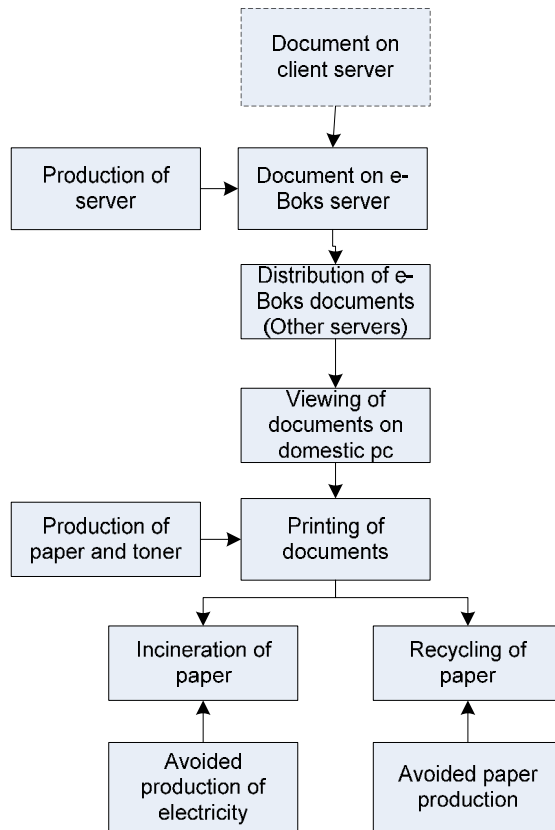


Figure 3. Main processes in the e-Boks system.

#### 6.3.1 Activities at e-Boks' clients

e-Boks offer its services to a wide range of clients that have a need for regularly distributing information to their customers. Typical examples are banks (sending bank account statements) and companies or institutions sending payslips to employees and invoice information to customers.

Generating the documents to be distributed requires a small amount of energy, e.g. in order to convert the basic information to a more suitable format. The environmental impacts from the client's generation of the information to be sent are assumed to be the same whether the information is sent by ordinary mail or electronically, and therefore these activities are outside the system boundaries of the study. In practice, very small differences may emerge, reflecting that some clients have in-house facilities for printing in the conventional system and therefore do not need to distribute the information electronically to a print shop. The same client will need to distribute the information electronically to e-Boks, causing a small additional consumption of energy.

### 6.3.2 e-Boks' activities

The environmental impacts of e-Boks' activities are in this study assumed to be almost solely related to the electricity consumed in handling the documents.

e-Boks is hosted by KMD, who was shareholder until recently. According to KMD, e-Boks activities made up 0.48% of the total amount of electricity consumed at KMD in 2008, equal to 83,638 kWh or 0.85 Wh per document.

The fraction consumed by e-Boks is calculated using the amount and capacity of servers as the allocation key. Using MIPS (Million Instructions Per Second) as the allocation key would give a slightly higher figure whereas using amount of stored information would give a slightly lower figure. The main consumption lies, however, with the servers and they are therefore chosen as the allocation key (Trine Thykier, KMD, pers. comm. February 2009).

The energy consumed by e-Boks in 2008 also includes storing and showing of all the documents that have been distributed since the start of e-Boks in 2001. Hence, using the total energy consumption to reflect the energy use for the 98.5 million documents is basically a conservative approach. On the other hand, there will be a future consumption of energy associated with the documents distributed in 2008, since documents will be stored until deleted by the user – or until e-Boks is notified by the authorities that the user is dead.

The approach thus provides a 2008 snapshot of the energy consumption. Future developments will most probably decrease the energy consumption per stored unit significantly. It is a general assumption that the density of transistors doubles every 18 or 24 months ("Moore's law"<sup>1</sup>), and in line with this it can be assumed that the energy consumption per unit stored in electronic media is halved every 18 or 24 months. Ten years from now the energy consumption per stored unit will thus be only 1/32 of what it is today. The potential error in using the 2008-snapshot as described above is therefore considered to be without practical importance.

Some of the energy is consumed because users want to view their documents. Of the 98.5 million documents distributed in 2008, about 48 million can be viewed directly from the e-Boks website, while the rest of the documents can only be opened from the website of the client. This is for example the case for many bank documents.

e-Boks logs the time the users are logged in to their e-Boks account. In 2008 this amounted to 94.4 million minutes or just about 2 minutes for each of the 48 million messages that can be accessed directly in e-Boks. The impacts from viewing the documents are described in the section "Domestic viewing of e-Boks", p. 31.

Besides the energy consumption for e-Boks' activities, there are environmental impacts associated with the production of IT equipment (servers). The servers are produced as a consequence of establishing and maintaining the e-Boks system and they are therefore included in the system examined.

Very little information is available on production of servers and in line with Moberg et al., 2008, data for production of desktop pc's were used as surrogate. In practice, it was assumed that one server equals two desktop computers. According to KMD (Michael Olsen, pers. comm. March 2009), the 98.5 million documents from 2008 can be stored on IT equipment, primarily a server, weighing about 6.5 kg. A pc weighs about 11 kg but it is not so densely populated with microchips as a dedicated server. The approach ensures thus that a potential contribution to the examined impacts categories is not overlooked, but it is evident that the uncertainty of this element alone may be large. It can, however, be seen from the results that the importance of the assumption is without practical importance in the given context.

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<sup>1</sup> [http://en.wikipedia.org/wiki/Moore's\\_law](http://en.wikipedia.org/wiki/Moore's_law)

## **Production of energy for e-Boks' activities**

KMD, the physical host for e-Boks, has decided to purchase electricity from newly developed wind turbines situated at Horns Rev in Denmark. The electricity from wind turbines come at a premium price, but KMD anticipates that savings identified and implemented by its electricity suppliers, primarily DONG Energy, will provide an adequate compensation. The expected savings in direct consumption are in the order of magnitude of 10% before 2010.

A main assumption behind this decision is that the consequence is that wind power capacity in Denmark will be increased, corresponding to the annual consumption by KMD. This approach is fully in compliance with the requirements in the Kyoto Protocol/ISO 14064-3 on validated greenhouse gas emission reductions. As described previously in the section "Production and consumption of electricity" the real effect of the approach may be doubted, and it is therefore chosen to account for the electricity used as if it comes from a modern coal-fired power plant.

### **6.3.3 Distribution and transmission of e-Boks' documents**

Distribution of messages and documents from e-Boks to its customers involves an Internet service provider who transmits the data. As a general rule we assume that e-Boks' documents are not stored by the internet service provider, whereas e-mail messages may be stored at the server for a relatively short period. Being very short messages, the energy consumption for storage of messages has been neglected, whereas their transmission is included.

The energy consumption for distribution and transmission of documents (and other types of data) can be deduced from the environmental reports published by major players in the ICT market. In Denmark, TDC is a dominant player, and Ole Willum has in a short note (Willum, 2008) combined the information available in the 2006 environmental report from TDC with in-house knowledge about the relationship between the capacity pull and the actual measured traffic in the TDC network.

Willum's calculations show that 1.4 kWh was consumed per GB (GigaByte) data transmitted in the TDC network in 2005. The data transmitted in the network are both TV-signals, internet and telephony in mobile and fixed networks, and the figure of 1.4 kWh/GB must thus be regarded as a crude estimate. The order of magnitude, however, compares to values given by other ICT companies, e.g. Swisscom and Telecom Italia. From Willum's note it is also evident that mobile telecommunication is far more demanding in energy terms than fixed networks, and the fact that 82% and 14% of the traffic was for cable TV and internet, respectively, therefore indicates that the figure of 1.4 kWh/GB used in calculations is a conservative assumption.

It is remarked that the 1.4 kWh/GB includes all types of energy consumption, i.e. also energy used for heating of buildings and transportation in company cars, etc. According to the 2006 environmental report from TDC, electricity consumption accounts for about 66% of the overall energy consumption. It is a general finding that electricity causes larger environmental impacts per consumed unit (e.g. kWh) than most other energy sources, and accounting for all energy consumed in distribution of e-Boks documents as electricity is regarded as a conservative approach which in no way underestimates the impacts of e-Boks.

With an average size of a distributed document of 38 KB, the energy consumption per document is 0.05 Wh or 5240 kWh in total. Compared to other activities in the value chain, the contribution from distribution is thus almost negligible.

### **6.3.4 Domestic viewing of e-Boks documents**

In order to use e-Boks, a person must have access to a computer. It is a basic assumption that a user of e-Boks will not purchase a computer for this purpose alone, but rather welcome

e-Boks as one of many services and possibilities which become available when a computer is purchased. As a consequence of this consideration, none of the impacts associated with production of a computer are assigned to the e-Boks system.

Using e-Boks is an integral part of using a computer. When the user is notified that there is a new message from e-Boks, we assume that she logs on to e-Boks, opens the document, reads it and eventually logs off the service again to return to e.g. the mail programme.

It was calculated from e-Boks information that the average time spent to read a document was two minutes (see "e-Boks' activities", p. 30). A user, however, also needs to log-on to the server from where the document can be accessed and as a conservative estimate we have assumed that this takes two minutes. Monitoring user behaviour at e-Boks in 2008 has revealed that once logged on, the user opens 1.6 documents in average. For one document the time used to log-on procedures is thus 1.25 minutes and in total, an e-Boks user will thus use their computer in 3.25 minutes per document in average.

The energy consumed during the viewing of the e-Boks document depends on the equipment used. A wide range of solutions are used today, with large differences between the energy intensity of the CPU, monitor, router, printer, etc. A fair average is established by using information about the properties of the stock of multimedia equipment in Danish households in 2006 (expressed in total kWh/year) and the use pattern (expressed in hours per year) also for Danish households. According to Rahbar, Larsen and Larsen (2008) the average amount of electricity used by domestic computer workstations was 397 kWh/year, including computer, monitor, router, scanner, printer and ADSL. According to Larsen (2007) the equipment was in average turned on 2398 hours per year. Combining the two sets of information it can be calculated that the energy consumption per "active" hour of use is 0.165 kWh (397/2398). For a four-minute viewing of a document, this corresponds to about 9 Wh.

### **Sensitivity analysis**

Average viewing time per document and average energy consumption for domestic ITC workstations can only be determined with some uncertainty. We believe that the assumptions being used for calculation of the base case scenario are relatively robust and that it is representative for today's users of e-Boks. It is, however, also evident that the conditions vary from one user to another, e.g. with respect to viewing time and IT equipment used. These variations are examined by applying a sensitivity analysis as outlined below.

Also described below are other suggestions for sensitivity analyses which could be of interest. The arguments behind them are, however, fairly radical and the results would basically only show the consequences if all (or none) of the impacts related to the use of IT equipment were allocated to the e-Boks system. Such approaches make little sense, but the short discussion shows that the possibility of including them have been considered – and to a large extent also discussed at a workshop with the stakeholders.

### **Viewing time**

With respect to viewing time, some users of e-Boks will spend significantly more time on their documents than the average user. For one reason or the other, documents of the e-Boks type may need to be scrutinized for several minutes, e.g. comparing bills with postings in a bank document. Another reason could be that some users have an old computer and/or a slow modem connection, which adds considerable time to the process. Therefore, we include a sensitivity analysis assuming that ten minutes is used for log-in and viewing of the document, instead of 3.25 minutes. It is emphasized that the outcome of this specific sensitivity analysis will give a very conservative estimate and we assume that very few users will find that their use of e-Boks is well reflected by this analysis.

Reducing the viewing time, e.g. to two and a half minute, will perhaps give a more realistic picture for users with fast internet connections. It has been chosen not to examine this option

in a sensitivity analysis, but it is evident that it will decrease the impacts (and increase the benefits) of the e-Boks system significantly.

### **IT equipment**

The energy consumed by the computer equipment (pc, monitor, router, ADSL and printer) was estimated using well-established averages for the equipment actually being used in Danish households in 2006. The result is considered to be robust on the system level, but it is not necessarily very representative for users with modern equipment, e.g. laptop computers with low energy consumption instead of desktop models. Also, the use of LCD monitors can significantly reduce the energy consumption compared to CRT monitors.

The current trend is that laptop computers are becoming more and more common, and especially small models are increasing their market share. To reflect this, we made a sensitivity analysis assuming that all e-Boks users have a laptop computer with an energy consumption of 40 W as compared to the combined use of desktop pc and monitor with a consumption of 100 W in total. In other words, laptop computers consumes 60 W less per hour – or 3.25 Wh less for viewing a document. This scenario can be regarded as a best case situation today with respect to the equipment being used, but it probably gives a realistic picture of the situation in a not so distant future, e.g. 6-10 years.

### **Green electricity**

Assuming that all electricity consumed is "green" is, as discussed previously, perhaps not unrealistic when examining the consequences on the system level. In the current project it may, however, be seen as a way of greenwashing the e-Boks system (and other electricity consuming activities) and we have therefore chosen to maintain the conservative assumption that all electricity consumed in Denmark is produced from coal. No sensitivity analysis is therefore made for this element.

### **Use pattern of computer equipment**

An increasing amount of time is spent at computer-related activities. Rahbar, Larsen and Larsen (2008) thus reports that the use intensity for people living in apartments has increased from 1043 hours per year in 2004 to 2250 hours per year in 2006, i.e. more than a doubling in just two years.

Not surprisingly, recent research based on interviews in Denmark, has shown that ICT is used for an increasing variety of purposes. It is outside the scope of the current project to go into any detail about this, but it is apparent from the research that many people have more than one computer per person and also that many people never turn their computer off for reasons of convenience or practical means.

For people who never turn their computer off, it can be argued that the use of e-Boks does not cause any additional energy consumption. The users may spend some extra time at the computer, but as it is in on-mode anyway there is no change in energy consumption. Using this scenario would – in the same way as assuming CO<sub>2</sub>-neutral electricity – cause the environmental impacts to decrease significantly, but it may likewise be seen as an effort to greenwash the system. A sensitivity analysis is therefore not made.

A major exception from this conclusion is if people acquires and uses a computer with the main purpose of having uninterrupted access to e-Boks. In such cases all energy consumed should be attributed to the e-Boks system (as well as the impacts from production of the computer). We assume, however, that this will only be the case for very few users, if any, and accordingly no sensitivity analysis is made of this element.

## **6.3.5 Domestic printing of e-Boks documents**

e-Boks' documents are stored at central servers and their content can be recalled in seconds until the account is closed. There is thus no immediate need for printing the documents, but

some customers nevertheless prints a document now and then, e.g. in order to show the information to other people or to make a closer scrutiny of the content away from the monitor.

A 2008 survey among 10,000 users of e-Boks showed that 39% never prints an e-Boks document and 47% only prints in rare instances. 14% of the users thus frequently made a print of their documents in this survey.

A supplementary survey was made in 2009, asking users of e-Boks how many documents they had opened in a session, and how many they had printed. Based on about 3000 answers, this survey showed that 15% of the documents being opened were also printed. According to e-Boks, this figure must be regarded as high, but it has nevertheless been used to calculate the impacts from production of paper for domestic printing. The reason why e-Boks considers 15% to be a conservative estimate is that a significant part of the documents stored in e-Boks are never opened and they will accordingly never be printed.

It is remarked that the consumption of energy for printing is included in the figure for domestic viewing of documents found in the previous section. As for central printing it has been assumed that the average document is 1.8 pages, but an envelope is obviously not included.

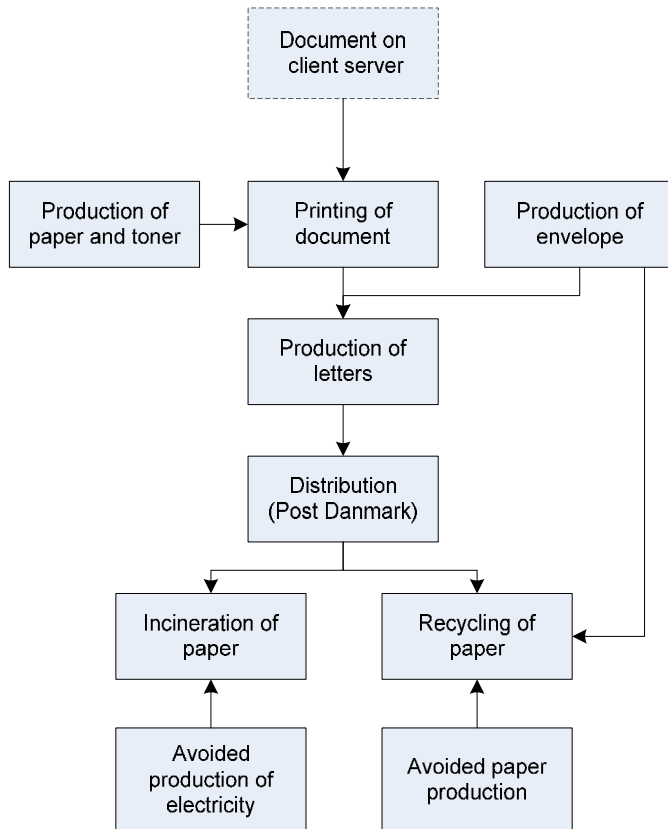
### **6.3.6 End-of-life of printed documents**

The end-of-life of printed documents is described previously, see "End-of-life of paper", p. 26.

## **6.4 *The conventional system***

The conventional system for distribution of bank account statements includes a wide range of processes. Being based on paper, the system includes forestry, production of pulp and paper, printing processes (and production of toner) as main upstream processes to the core element, physical distribution of the documents by PostDanmark. The basic elements in the system are shown in Figure 4.

It is noted that the assumptions made for production and end-of-life of paper are similar in the two systems, the only exception being that all paper waste generated in production of envelopes is assumed to be recycled into woodfree and uncoated paper. The impacts from printing and distribution are different, as described in relevant sections.



**Figure 4. Main processes in the conventional distribution system.**

### 6.4.1 Production of envelopes

Almost all documents are distributed in window envelopes, format M5 or M65. Data for production of envelopes were established using information from Konvolut Danmark (Martin Kiilsgaard, pers. comm., March 2009). Data are assumed to be representative for standard envelopes with an acetate window:

**Table 2. Consumption of raw materials and energy in envelope production, incl. losses.**

Element	Size M5 (paper quality 90 g/m <sup>2</sup> )	Size M65 (paper quality 90 g/m <sup>2</sup> )
Paper	7.66 g	5.69 g
Acetat (window)	0.20 g	0.20 g
Glue (dry matter)	0.2 g	0.2 g
Flexo ink	0.185 g	0.15 g
Electricity (average)	5.56 Wh	5.56 Wh

Loss of paper in the production process is assumed to be 14%. The waste paper is collected and recycled into office paper after de-inking, and is assumed to substitute virgin office paper.

In the calculations we have assumed that equal amounts of the two envelope sizes are used.

### 6.4.2 Printing and enveloping of documents

Some of e-Boks' clients have in-house printing facilities while others have outsourced the process of printing/enveloping the documents.

The environmental impacts from printing and enveloping have been included, primarily based on information from Strålfors, a major Danish supplier of printing, labelling and enveloping services.

In practice, a wide range of products and processes are available. As examples can different envelopes and paper qualities be used; both duplex and simplex printing is possible, and the printing equipment can print on parallel lengths of paper.

For an average product with 3.7 so-called images (a print on one side of a page), the amount of electricity consumed is 3.1 Wh. We assume that half of this is used in the enveloping process and the rest is used in printing. Since the average document in e-Boks is only about two pages (and two images), we have reduced the energy for printing accordingly. For a two-page document in an envelope the consumption of electricity is thus 2.5 Wh. This is about half of the amount assumed in the Swedish study by Moberg et al. (2008), but is believed to reflect a highly efficient production in Denmark. It is, however, also noticed that the figure does not include overhead consumption for lighting etc., which is assumed to constitute about 25% of the total (Rikke Lüth, Strålfors, pers. comm. March 2009).

According to Strålfors, the consumption of toner is 0,048 g per printed page with coverage of 3%. This is about twice as much as assumed in the Swedish study, but since it has no visible influence on the results, no efforts have been devoted to a closer examination.

About 50% of the sheets are pre-printed with logo and address before being printed at Strålfors. We have assumed a sheet-fed offset printing method similar to that described in Larsen et al. (2006) with an energy consumption of 0.705 MWh/ton – or 3.12 Wh per average page. Other impacts from the pre-printing process, e.g. related to transportation as well as production of toner and aluminium plates have been neglected.

### **6.4.3 Distribution of letters**

Bank account statements are assumed to be distributed in the same way as other non-priority letters. To account for the environmental impacts, Post Danmark provided a very recent update on the consumption of electricity and diesel per gram letter distributed (Søren Boas, Post Danmark, pers. comm. March 2009):

Electricity:	0.0001 kWh/g
Diesel:	0.0000796 l/g

The amount of electricity consumed only covers the need for handling of letters. Electricity used for lighting and other overhead activities is not changed to a significant extent as a consequence of a reduced amount of letters being distributed and is therefore not included. The same argument is valid for other types of fixed energy consumption, e.g. for heating purposes.

Post Danmark also makes use of local transport service providers to distribute some of its letters and parcels. The contribution from this is included in the above figures.

### **6.4.4 End-of-life of printed documents and envelopes**

The end-of-life of printed documents and envelopes is described previously, see "End-of-life of paper", p. 26.

## 6.5 Data processes and data quality

Table 3 provides an overview of the database processes used in the calculations. It is evident that most of the ecoinvent processes used addresses average processes rather than those actually affected by an increased or decreased production consequential to the change to electronic distribution.

It is outside the scope of the current project to identify which paper producers and paper recyclers who actually are affected and collect data from these. We believe, however, that the data used are of good quality, giving a representative estimate of the changes associated with use of the e-Boks system. It is however, also remarked that data on paper production and recycling have been established using a wide range of sources with very different levels of detail. A thorough description of data sources and data quality can be found in specific ecoinvent document, e.g. Hischer (2007).

**Table 3. Overview of database processes used in the calculations.**

Process	Source	Process name	Comment
Electricity	GaBi/EDIP	Coal power plants 2001	Marginal electricity production in Denmark, allocated by exergy
Production of servers	Ecoinvent	GLO: desktop computer, without screen, at plant	Two desktop PCs used as a proxy for one server
Paper production	Ecoinvent	RER: paper, woodfree, uncoated, at regional storage	
Paper waste collection	Ecoinvent	CH: waste paper, mixed, from public collection, for further treatment	For incineration
Transport of paper	Ecoinvent	CH: transport, lorry >28t, fleet average GLO: Transoceanic ship	Transoceanic ship was chosen for what is assumed to be a large coaster or bulk-carrier
Paper waste incineration	Ecoinvent	AD: disposal, paper, 11.2% water, to municipal incineration	Energy recovery according to Danish conditions as outlined by Schmidt and Strömberg (2006)
Paper waste recycling	Ecoinvent	RER: paper, newsprint, DIP containing, at plant RER: paper, newsprint, 0% DIP, at plant RER: paper, recycling, with deinking, at plant	Recycling in Sweden and Germany  Substituted production  Recycling of envelope paper waste
Toner	Ecoinvent	GLO: toner, black, powder, at plant	Only black toner assumed as input
Diesel	Ecoinvent	RER: diesel, low-sulphur, at regional storage RER: operation, lorry 16-32t, EURO3 RER: operation, lorry 16-32t, EURO4	Modelled as extraction + combustion in trucks (50% EURO3 and 50% EURO4 standard)

## 7 Results of the impact assessment

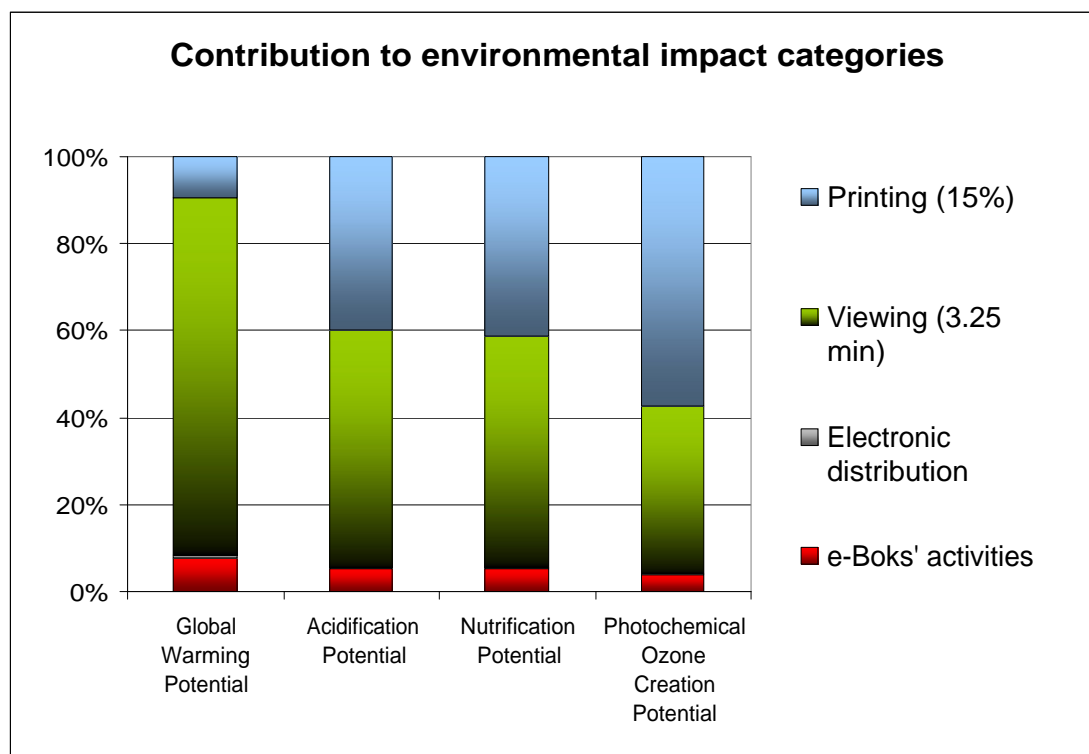
### 7.1 The e-Boks system

The environmental impacts from delivery of 98.5 million documents in the e-Boks system (baseline scenario) are presented in Table 4, together with information regarding the consumption of energy from fossil and renewable resources.

**Table 4. Environmental impacts and energy use caused by delivery of 98.5 million documents in the e-Boks system**

Impact category	Unit	Total e-Boks	e-Boks' activities	Electronic distribution	Viewing	Printing
Global Warming Potential	kg CO <sub>2</sub> -eq.	<b>947,205</b>	74,372	4,625	779,641	88,568
Acidification Potential	kg SO <sub>2</sub> -eq.	<b>2,904</b>	157	9	1,576	1,162
Nutrifaction Potential	kg NO <sub>3</sub> -eq.	<b>3,757</b>	193	12	2,001	1,551
Photochemical Ozone Creation Potential	kg C <sub>2</sub> H <sub>4</sub> -eq.	<b>135</b>	5	0	52	78
Total energy consumption	MJ	<b>12,682,608</b>	998,982	61,963	10,445,147	1,176,515

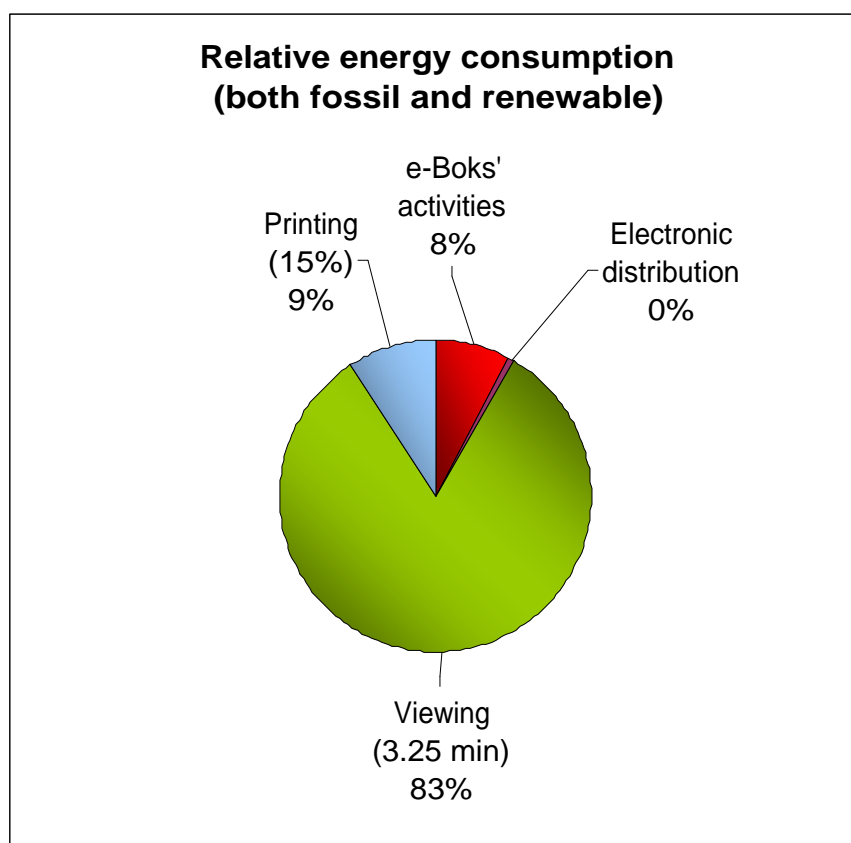
It appears from Table 4 that viewing of e-Boks documents is the most important activity with respect to global warming/climate change and consumption of energy, accounting for about 80-85% of the total impacts. Both global warming and total energy consumption is closely related to production of electricity, and it is therefore not surprising that viewing of the documents is most important. Figure 5 clearly illustrates the relative importance of the life cycle activities with respect to the four environmental impact categories.



**Figure 5. Relative importance of life cycle activities in the e-Boks system with respect to the four environmental impact categories**

With respect to acidification and nutrification, viewing and printing are of almost equal importance, together accounting for about 95% of the overall impacts. For photochemical ozone ("smog") creation, printing is most important, accounting for more than 50% of the total contribution. "Printing" as activity includes primarily production and disposal of paper whereas electricity for the printer is accounted for under viewing. Especially papermaking processes are therefore of importance in this context.

Figure 6 shows the relative importance of the life cycle activities with respect to the total consumption of energy, i.e. the aggregated value for both fossil and renewable fuels. It is noted that renewable fuels play a very minor role in this picture, accounting for less than 0.3% of the total.



**Figure 6. Relative energy consumption in different life cycle activities in the e-Boks system**

In the overall context, the activities at e-Boks (primarily storing and handling of documents at KMD) play only a minor role. Most influence is observed with respect to global warming potential and consumption of energy, where the activity accounts for about 7%. Production of servers for e-Boks documents is without any practical importance in the overall picture.

The consumption of selected resources in the different life cycle activities is presented in Table 5.

**Table 5. Consumption of selected resources in the e-Boks life cycle**

Resource	Unit	e-Boks	e-Boks' activities	Electronic distribution	Viewing	Printing
Crude oil	kg	<b>19,900</b>	638	38	6,339	12,885
Hard coal	kg	<b>433,400</b>	38,457	2,404	405,237	-12,698
Lignite	kg	<b>7,625</b>	124	1	150	7,350
Natural gas	kg	<b>20,927</b>	165	8	1,281	19,473
Uranium	g	<b>0.09</b>	0.01	0.00	0.04	0.05
Wood	m <sup>3</sup>	<b>266</b>	0	0	0	266

Consumption of hard coal is – as judged by weight – the most important resource addressed in the study of the e-Boks system. This is not surprising because it is a general assumption that all electricity used for e-Boks' activities (primarily storage), electronic distribution and viewing is produced in coal-fired power plants. It is therefore also not surprising that "Printing" (including paper production and disposal) is the most important activity with respect to other resources since wood in the primary raw material in paper production and a wide range of energy sources are used in the average European production.

It is noted at this point that the figures are assumed to give a fair, but probably conservative overview of the environmental impacts. The impacts from the printing process may be overestimated, because it is assumed that 15% of all documents being available on the KMD server are printed. In practice, a somewhat smaller amount is printed, but it has not been possible to make a more precise estimate from the user surveys performed. Also the impacts from viewing the documents may be overestimated. It is assumed that it takes two minutes to log-on to e-Boks when the user becomes aware that a new document is available, but for many users the time used is significantly less, perhaps only one minute.

## 7.2 The conventional system

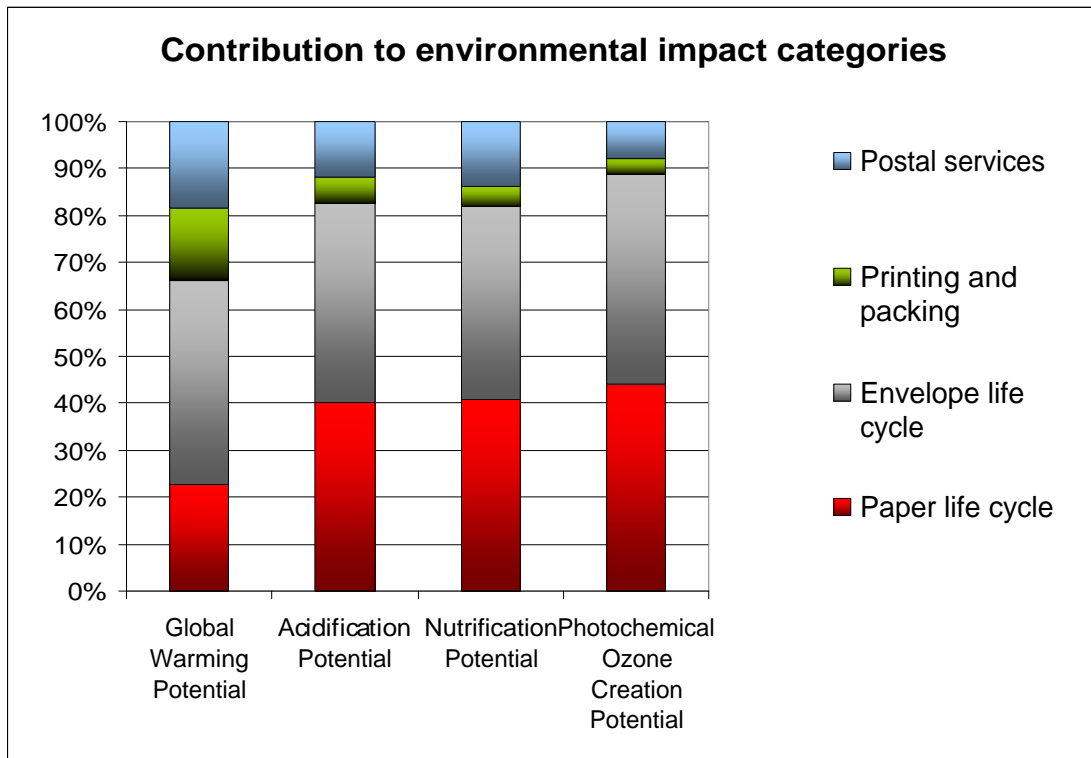
The environmental impacts from delivery of 98.5 million documents in the conventional system (baseline scenario) are presented in Table 6, together with information regarding the consumption of energy from fossil and renewable resources.

**Table 6. Environmental impacts and energy use caused by delivery of 98.5 million documents in the conventional system**

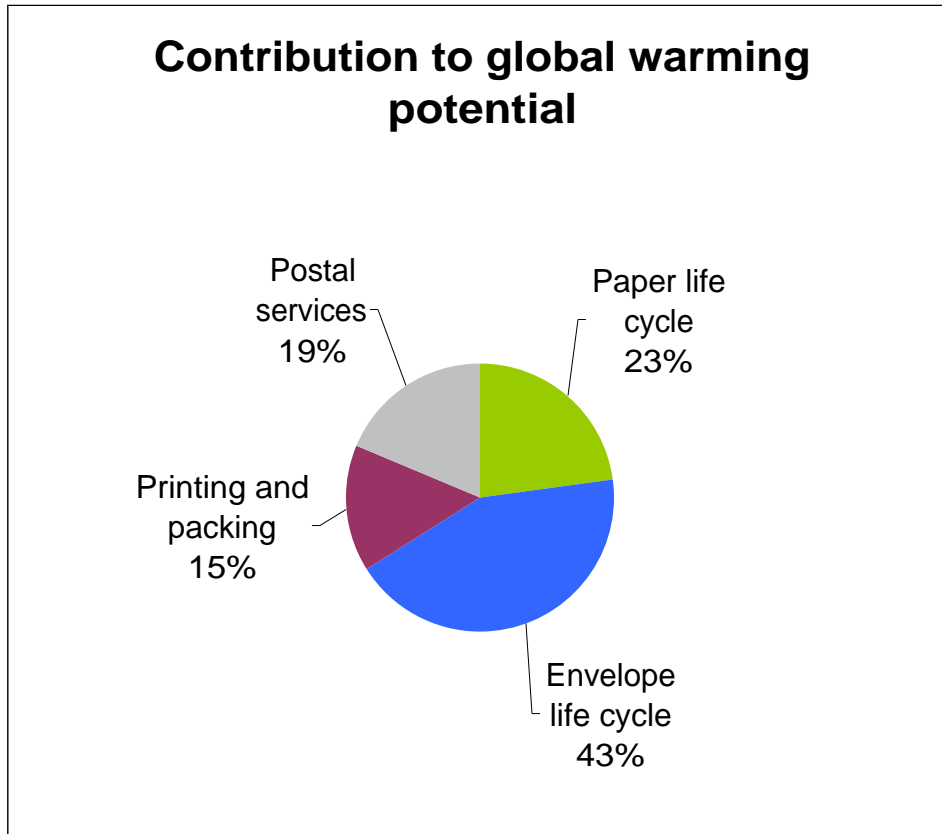
Impact category	Unit	Conventional mail distribution	Paper life cycle	Envelope life cycle	Printing and packing	Postal services
Global Warming Potential	kg CO <sub>2</sub> -eq.	<b>2,599,701</b>	590,454	1,126,323	399,993	482,931
Acidification Potential	kg SO <sub>2</sub> -eq.	<b>19,319</b>	7,746	8,188	1,071	2,313
Nutrification Potential	kg NO <sub>3</sub> -eq.	<b>25,251</b>	10,339	10,376	1,086	3,450
Photochemical Ozone Creation Potential	kg C <sub>2</sub> H <sub>4</sub> -eq.	<b>1,174</b>	519	523	38	95
Total energy consumption	MJ	<b>37,358,088</b>	7,843,422	17,014,454	5,951,864	6,548,348

It appears from Table 6 that the life cycle of the envelopes gives the largest contribution in all examined impact categories, followed by the life cycle of the paper, i.e. the core document. Postal services are also important, especially with respect to global warming potential and total energy consumption, accounting for more than 15% of the total. Printing the documents and packing them in envelopes account for 3-15%.

Figure 7 illustrates the contribution to the environmental impacts from the four life cycle activities analysed in the study of the conventional system. As outlined above, paper and envelope production are the most important activities, together accounting for more than two thirds of the total impacts. As can be seen from Figure 8, this picture also applies to total energy consumption.



**Figure 7. Relative contribution from the activities in the conventional system to the four environmental impact categories**



**Figure 8. Relative energy consumption in different life cycle activities in the conventional system**

The consumption of resources in the different activities in the conventional system is shown in Table 7.

**Table 7. Resource consumption caused by delivery of 98.5 million documents in the ordinary mail system**

Resource	Unit	Conventional mail distribution	Paper life cycle	Envelope life cycle	Printing and packing	Postal services
Crude oil	kg	<b>307,569</b>	85,901	108,786	9,914	102,968
Hard coal	kg	<b>390,190</b>	-84,655	209,568	189,984	75,293
Lignite	kg	<b>121,202</b>	49,003	58,610	10,640	2,949
Natural gas	kg	<b>275,074</b>	129,820	132,235	8,546	4,473
Uranium	g	<b>1.49</b>	0.31	0.83	0.28	0.08
Wood	m <sup>3</sup>	<b>3,180</b>	1,775	1,404	1	0

As judged by weight hard coal appears to be the most important resource, but the consumption of crude oil, lignite and natural gas is of the same order of magnitude. This is not surprising, since most of the electricity consumed is assumed to be produced in coal-fired power plants whereas especially crude oil and natural gas is used to produce the thermal heat for production of paper, and crude oil is used to produce fuels for transportation.

### **7.3 Consequences of changing to electronic distribution**

The results presented above for the two systems can be seen as a declaration of the environmental impacts associated with the distribution of 98.5 million documents by conventional distribution or by electronic distribution.

The environmental consequences of using e-Boks as an alternative to conventional distribution of documents by ordinary mail can therefore be calculated by subtracting the impacts of the conventional system from the impacts of the e-Boks system. If the results are negative, the environmental impacts are reduced and a benefit for the environment is achieved.

### 7.3.1 Benefit for the environment in all examined impact categories

As can be seen from Table 8 the results are in fact negative in all examined impact categories.

**Table 8. Changes in the environmental impacts and energy use as a consequence of distributing 98.5 million documents through e-Boks instead of by ordinary mail**

Impact category	Unit	Change
Global Warming Potential	kg CO <sub>2</sub> -eq.	-1,652,496
Acidification Potential	kg SO <sub>2</sub> -eq.	-16,415
Nutrication Potential	kg NO <sub>3</sub> -eq.	-21,493
Photochemical Ozone Creation Potential	kg C <sub>2</sub> H <sub>4</sub> - eq.	-1,039
Total energy consumption	MJ	-24,675,481

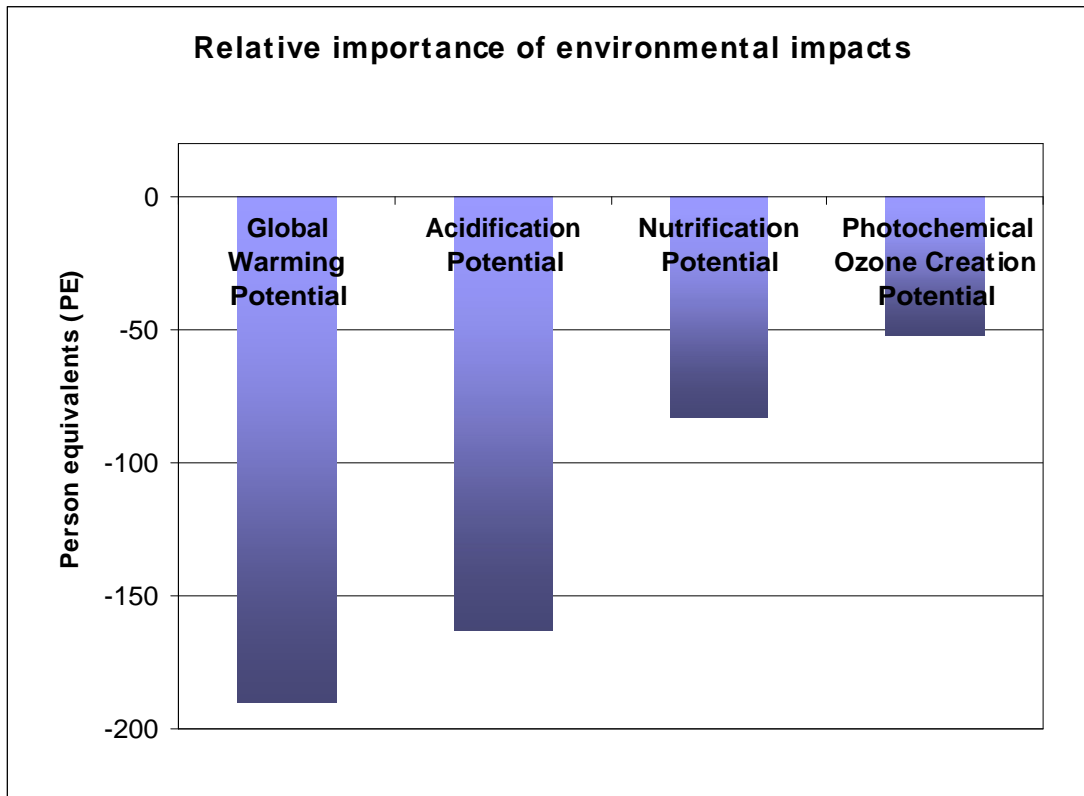
The contribution to all environmental impacts is reduced and an environmental benefit is achieved. It is thus a straightforward conclusion that with the given preconditions, distributing automatically generated documents in the e-Boks system has less impact on the environment than conventional distribution by ordinary mail.

### 7.3.2 Which benefit is most important?

The Danish EDIP method (Hauschild & Wenzel, 1998) gives the possibility of investigating which benefit that can be regarded as the largest or most important. In order to do this, all results are normalised with respect to the impacts caused by an average citizen in the affected geographical area, the so-called "Person Equivalent" or PE. The Person Equivalent is calculated as the background impact over the course of one year caused by one person in the area for which the impact is computed. It is important to include the geographical aspect, simply because some environmental impacts have a global scale (e.g. global warming/greenhouse effect), while others are regional in scale, e.g. acidification causing forest die-back in some areas.

For the normalisation 1994 is used as the reference year. The method and data used for calculation of the Person Equivalent or normalisation reference is described in detail in Stranddorf et al. (2005). It would obviously be more satisfying to use more recent data for the normalisation, but these are unfortunately not available.

The normalised results are presented in Figure 9.



**Figure 9. Normalised environmental impacts as caused by a change from ordinary mail distribution to the e-Boks system, expressed as person equivalents.**

It appears that the reduced contribution to global warming/climate change is most important. When electronic distribution is used instead of distribution by ordinary mail the reduction corresponds to the annual emissions of 190 average Danish citizens. The reduction in the contribution to acidification is of the same magnitude with a reduction similar to that caused by 163 average citizens in a year. In this context, the reduction with respect to nutrification and photochemical ozone creation is of less importance, corresponding to 85 and 52 person equivalents, respectively.

The EDIP method does not allow for a similar calculation of the importance of the energy consumption. According to the Danish Energy Agency, Denmark had a gross energy consumption of 873 PJ (Peta Joule) in 2007 corresponding to 159,000 MJ per citizen. Using this figure, the total energy savings achieved as a consequence of using e-Boks for distribution corresponds to the consumption of energy of 155 average Danes, i.e. a figure which is comparable to that of savings in global warming potential. It is underlined that the energy calculations are not a part of a formalised and well-documented methodology, but should rather be seen as a confirmation of the robustness of the calculations.

Another way of looking at the energy savings is by using the so-called "Oil Equivalent" as suggested by OECD. One ton Oil Equivalent equals 41.868 GJ and the savings in the e-Boks system therefore corresponds to about 580 tonnes Oil Equivalents. As shown in Table 9 the savings are distributed on all types of fossil fuels, but it is evident that the most prominent savings are found with respect to crude oil (used for e.g. production of transportation fuels like diesel and gasoline) and natural gas. Both of these resources are relatively scarce compared to e.g. coal and uranium.

**Table 9. Energy savings distributed on different energy sources.**

Energy source	kg	MJ
Crude oil	-287,670	-12,309,350
Hard coal	43,210	1,139,618
Lignite	-113,577	-1,303,812
Natural gas	-254,147	-10,941,401
Uranium	-1.399	-1,261,457

## 7.4 Sensitivity analysis

The results presented in the previous sections all refer to the baseline scenario, i.e. the scenario assumed to reflect actual conditions in the best possible and most precise way.

In a study of this type, however, a large number of assumptions have to be made, e.g. regarding energy consumption when viewing the documents and how often a document is printed by the e-Boks user. Care has been exercised to find or establish adequate information for the calculations, but a sensitivity analysis as applied in the following sections is useful in both an assessment of the robustness of the results and as an indicator of where in the value chain changes may have the largest effect, e.g. further reducing the environmental impacts from distribution of documents.

### 7.4.1 Printing frequency

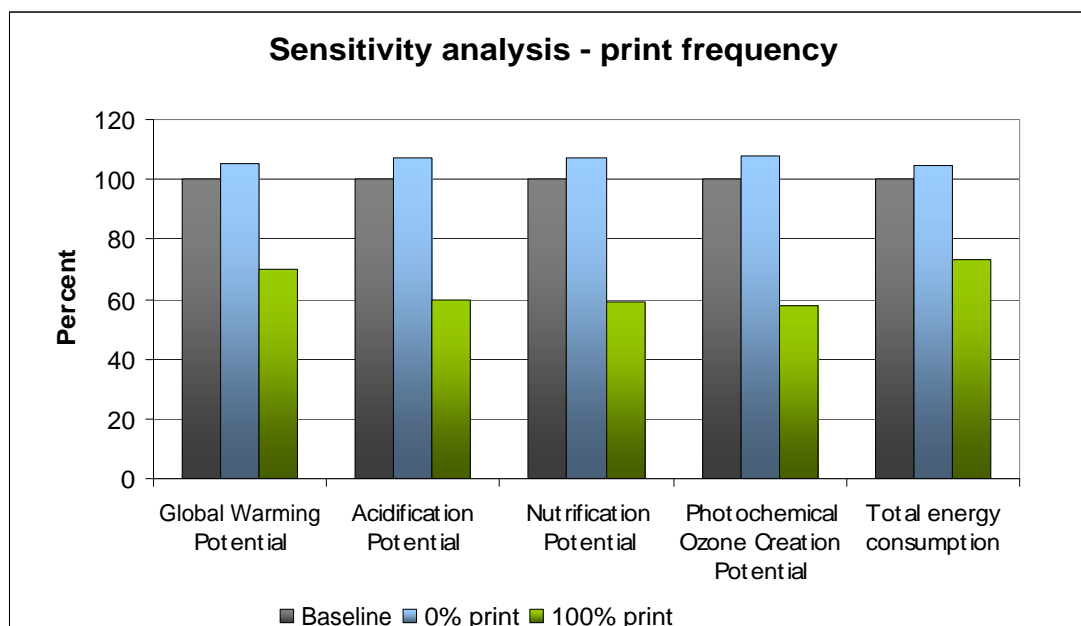
The printing frequency, i.e. how often an e-Boks user prints a document, was determined by asking users of e-Boks how many documents they had opened in a given session and how many they had printed. Based on a sample of about 3000 answers it was concluded that 15% of the documents opened by the users were also printed.

The baseline scenario showed that printing of the documents was responsible for a significant part of the environmental impacts, e.g. 40% of the contribution to acidification, 9% of the contribution to global warming and 10% of the consumption of fossil fuels.

A sensitivity analysis was applied in order to show how the environmental benefits change if no-one prints their documents or if all documents are printed. Neither of these scenarios is realistic but they can illustrate the difference between printing a document and not printing a document for current and future users of e-Boks. The savings in absolute figures are shown in Table 10 while the relative changes are shown in Figure 10.

**Table 10. Environmental impacts as a function of printing frequency in the e-Boks system (more negative figures indicates larger benefits).**

	Unit	Baseline (15% print)	0% print	100% print
Global Warming Potential	kg CO <sub>2</sub> -eq.	-1,652,496	-1,741,064	-1,150,610
Acidification Potential	kg SO <sub>2</sub> -eq.	-16,415	-17,577	-9,831
Nutrication Potential	kg NO <sub>3</sub> -eq.	-21,493	-23,044	-12,706
Photochemical Ozone Creation Potential	kg C <sub>2</sub> H <sub>4</sub> - eq.	-1,039	-1,117	-598
Total energy consumption	MJ	-24,675,481	-25,851,996	-18,008,574



**Figure 10. Environmental impacts relative to the baseline scenario (15% printing) as a function of printing frequency. Figures higher than 100% indicates an additional benefit compared to baseline.**

The sensitivity analysis shows that the environmental benefits are decreased significantly if all documents are printed. This is not a realistic scenario, but the figures indicate that the general benefits from using the e-Boks system decrease with 30% or more when a user prints a document. The environmentally conscious user should therefore carefully consider which documents needs to be printed – and which not. It must be kept in mind in this context that some of the documents contain very important information from an economic point of view and this information shall of course be treated in the best possible way for the user, with little or no regard to the potential environment benefits from an avoided printing of the document.

The sensitivity analysis also shows that a further reduction of about 5-7% can be achieved in all impact categories if none of the 98.5 million documents were printed.

### 7.4.2 End-of-life of paper and envelopes

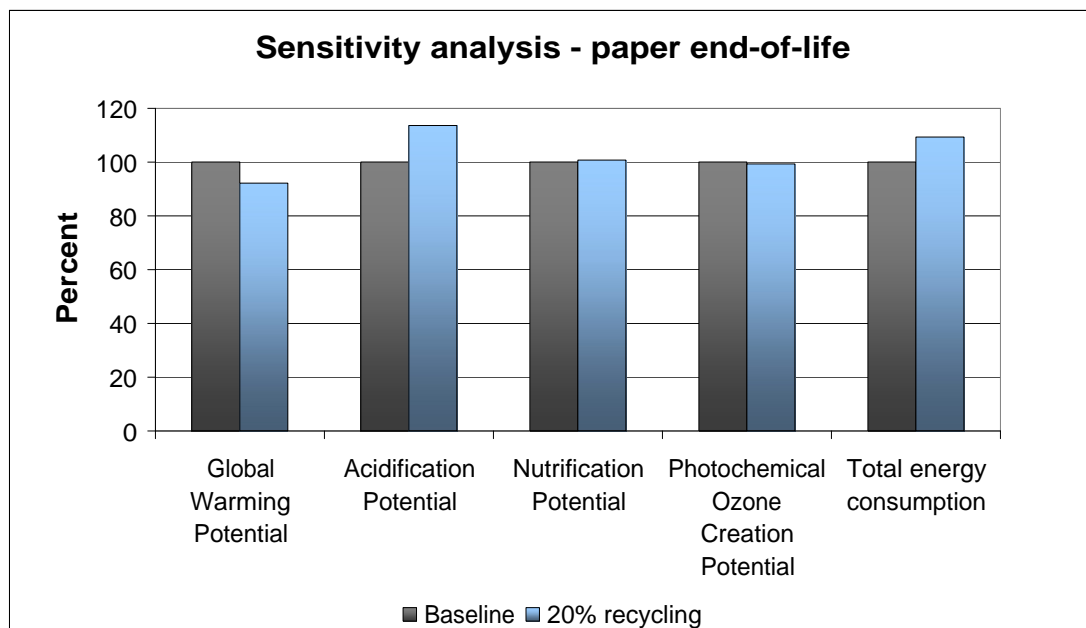
In the baseline scenario it was assumed that 60% of the paper and envelopes used in the systems is recycled, while the remaining 40% is incinerated with energy recovery. This assumption is in line with the current situation in 2008, and only small changes are foreseen as a consequence of regulatory initiatives.

The 60/40 distribution assumed is an average for all paper and cardboard waste collected from Danish households. As documents of the e-Boks type often contains highly personal/financial information some persons may choose to deliberately dispose of their paper waste to incineration, thereby assuming that the documents are destroyed safely with almost no risk of the documents being found and misused by other parties.

Therefore, we have chosen to make a sensitivity analysis, calculating the consequences if only 20% was recycled and the remaining 80% incinerated with energy recovery. The results of this calculation are shown in Table 11 (absolute figures) and in Figure 11 (relative difference).

**Table 11. Environmental impacts as a function of paper recycling percentage (more negative figures indicates larger benefits).**

	Unit	Baseline (60% recycling 40% incineration)	20% recycling/ 80% incineration
Global Warming Potential	kg CO <sub>2</sub> -eq.	-1,652,496	-1,524,281
Acidification Potential	kg SO <sub>2</sub> -eq.	-16,415	-18,689
Nutrition Potential	kg NO <sub>3</sub> -eq.	-21,493	-21,713
Photochemical Ozone Creation Potential	kg C <sub>2</sub> H <sub>4</sub> - eq.	-1,039	-1,029
Total energy consumption	MJ	-24,675,481	-26,961,045



**Figure 11. Environmental impacts relative to the baseline scenario (60% recycling/40% incineration) as a function of recycling percentage. Figures higher than 100% indicates an additional benefit compared to baseline.**

Changing the distribution of recycling and incineration ratios towards more incineration has a larger effect on the conventional distribution system than the e-Boks system. The reason for this is simply that more paper is used in the conventional system.

An increase in incineration will decrease the benefits with respect to climate change, but at the same time there are increased benefits with respect to acidification and consumption of fossil fuels. The outcome probably depends heavily on the availability of both fossil and renewable resources for both recycling and production of virgin paper, and the findings for this element of the study should therefore be interpreted with great care.

### 7.4.3 Time used to view documents

e-Boks logs the time the users are logged in to their e-Boks account. In 2008 this amounted to just about two minutes for each of the 48 million messages that can be accessed directly in e-Boks. A user must, however, also use some time to log-on to the server from where the document can be accessed and as a conservative estimate we have assumed that this takes two minutes. Monitoring user behaviour has shown that in average 1.6 documents is viewed per log-on and accordingly, 1.25 minutes is used per document for log-on procedures. An e-Boks user thus use the computer for 3.25 minutes per document viewed in average.

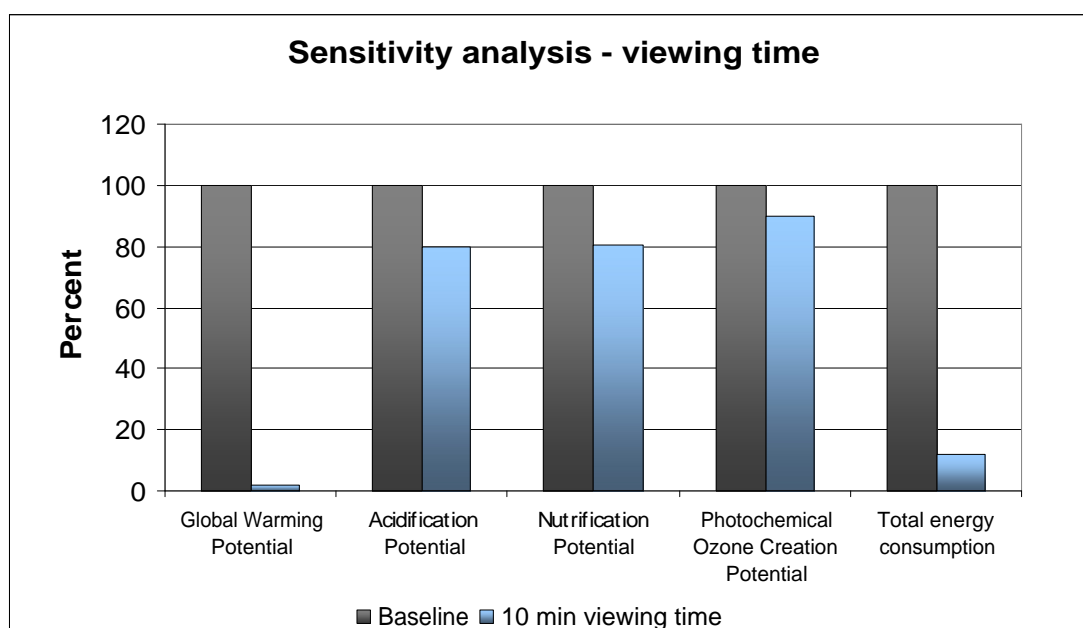
Some users may, however, use longer time to view a document. One reason could be that they want to scrutinize the document, e.g. comparing bills with postings in the document. Other users may have an old computer and/or a slow modem connection, adding considerable time to the log-on process.

In a sensitivity analysis we have assumed that the average viewing time is 10 minutes. This scenario is not realistic for the e-Boks system as a whole, but it gives a good indication of whether there are environmental benefits also for those users who for some reason spend relatively long time at the computer viewing their documents.

The results of the sensitivity analysis are shown in Table 12 (absolute figures) and Figure 12 (relative changes).

**Table 12. Environmental impacts as a function of viewing time (more negative figures indicates larger benefits).**

	Unit	Baseline (3.25 min viewing time)	10 min viewing time
Global Warming Potential	kg CO <sub>2</sub> -eq.	-1,652,496	-33,243
Acidification Potential	kg SO <sub>2</sub> -eq.	-16,415	-13,142
Nutrication Potential	kg NO <sub>3</sub> -eq.	-21,493	-17,337
Photochemical Ozone Creation Potential	kg C <sub>2</sub> H <sub>4</sub> - eq.	-1,039	-931
Total energy consumption	MJ	-24,675,481	-2,981,718



**Figure 12. Environmental impacts with a 10 min viewing time relative to the baseline scenario (3.25 min viewing time). Figures higher than 100% indicates an additional benefit compared to baseline.**

The sensitivity analysis shows primarily that the environmental benefits in form of a reduction of global warming potential and consumption of energy almost disappear when a document is viewed for 10 minutes. The simple reason for this is that the consumption of additional electricity causes large emissions of greenhouse gases. The other impact categories investigated are only affected to a minor extent, less than 20%.

As the sensitivity analysis addresses differences in the behaviour of the single user more than the full systems, the results should not be interpreted at the systems level, but they may be used in information directed at the users.

Thus, when combining the findings with the results from the sensitivity analysis of print frequency it appears that it may be a better solution from an environmental point of view to make a print of a document than to view on the computer screen for extended periods of time. It has, however, not been possible within the time frame of the current study to make a dedicated examination of the "best possible" way of handling documents in the e-Boks system.

#### 7.4.4 Alternative specifications of IT equipment

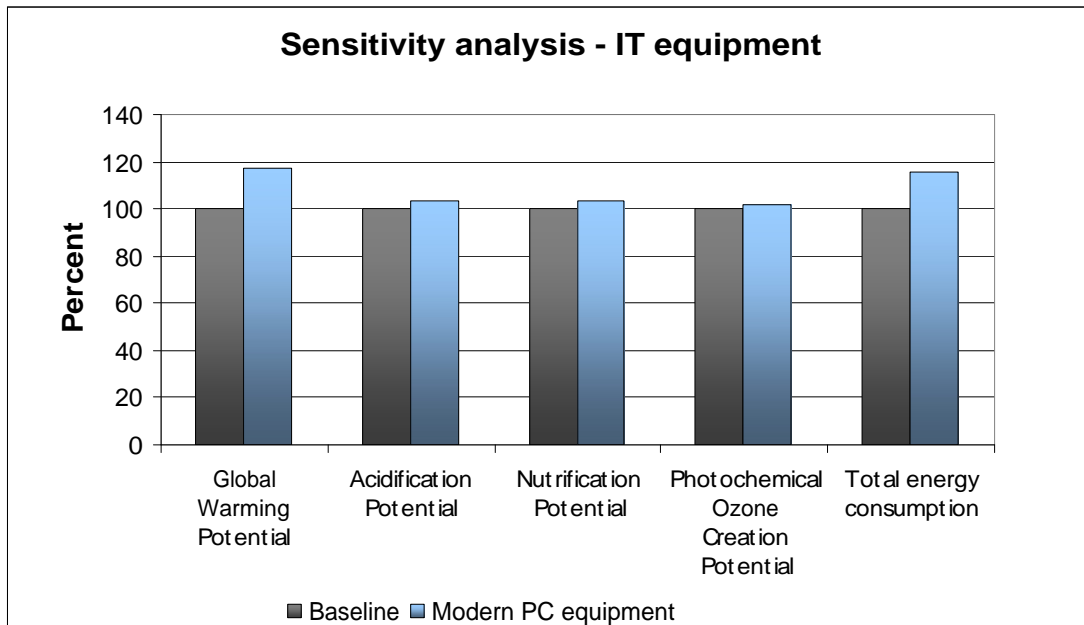
The energy consumed by the computer equipment (pc, monitor, router, ADSL and printer) was estimated for the baseline scenario using well-established averages for the equipment actually being used in Danish households in 2006. This estimate is not necessarily very representative for users with modern equipment, e.g. laptop computers (especially small models) with low energy consumption instead of desktop models. Also, the use of LCD monitors can significantly reduce the energy consumption compared to CRT monitors.

A sensitivity analysis was therefore made, assuming that all e-Boks users have a laptop computer with an energy consumption of 40 W as compared to the combined use of desktop pc and monitor with a consumption of 100 W in total. In other words, laptop computers consumes 60 W less per hour – or 3.25 Wh less for viewing a document. This scenario can be regarded as a best case situation today with respect to available equipment, but it probably gives a realistic picture of the average situation in a not so distant future, e.g. 6-10 years.

The results of the sensitivity analysis are shown in Table 13 (absolute values) and Figure 13 (relative values).

**Table 13. Environmental impacts as a function of IT equipment. Baseline equipment is average Danish stock in 2006; "Modern" equipment is a laptop computer. (More negative figures indicate larger benefits)**

	Unit	Baseline equipment	Modern PC equipment
Global Warming Potential	kg CO <sub>2</sub> -eq.	-1,652,496	-1,935,052
Acidification Potential	kg SO <sub>2</sub> -eq.	-16,415	-16,986
Nutrication Potential	kg NO <sub>3</sub> -eq.	-21,493	-22,219
Photochemical Ozone Creation Potential	kg C <sub>2</sub> H <sub>4</sub> - eq.	-1,039	-1,058
Total energy consumption	MJ	-24,675,481	-28,460,991



**Figure 13. Environmental impacts using laptop computers relative to average IT equipment. Figures higher than 100% indicates an additional benefit compared to baseline.**

The sensitivity analysis shows that the benefits are closely related to the energy efficiency of the IT equipment used to view the documents. The performance of the e-Boks system will most probably improve over time with more energy efficient IT equipment (laptop computers) replacing the existing stock of equipment in the Danish households. The improvement is significant, most prominently with respect to global warming potential (17% improvement) and consumption of energy (15% improvement).

It is remarked that the future stock of IT equipment not necessarily will be more energy efficient than today's stock. Powerful desktop computers are used by many for gaming activities and they will inherently consume more energy than the average computer used in the baseline scenario. If this type of computer is used also for viewing e-Boks documents, the benefits of the total system will probably be smaller than in the baseline scenario.

#### **7.4.5 Sensitivity analysis – summary**

The results of the sensitivity analysis are summarized in Table 14. No efforts have devoted to examine the outcome if the different sensitivity scenarios are combined. It is, however, obvious that the environmental benefits are significantly smaller for users who both view their documents for an extended period of time and print all their documents. Users, who use less time than 3.25 minutes to view the documents and who never or seldom prints the documents will provide benefits that are significantly larger than in the baseline scenario.

**Table 14. Overview of the results of the single elements in the sensitivity analysis.**

	Unit	Scenarios					
		Baseline	20% recycling	10 min viewing time	Modern PC equipment	0% print	100% print
<b>Environmental impact category</b>							
Global Warming Potential	kg CO <sub>2</sub> -eq.	-1,652,496	-1,524,281	-33,243	-1,935,052	-1,741,064	-1,150,610
Acidification Potential	kg SO <sub>2</sub> -eq.	-16,415	-18,689	-13,142	-16,986	-17,577	-9,831
Nutrication Potential	kg NO <sub>3</sub> -eq.	-21,493	-21,713	-17,337	-22,219	-23,044	-12,706
Photochemical Ozone Creation Potential	kg C <sub>2</sub> H <sub>4</sub> - eq.	-1,039	-1,029	-931	-1,058	-1,117	-598
Total energy consumption	MJ	-24,675,481	-26,961,045	-2,981,718	-28,460,991	-25,851,996	-18,008,574
<b>Resource consumption</b>							
Crude oil	kg	-287,670	-286,054	-274,504	-289,967	-300,555	-214,653
Hard coal	kg	43,210	116,933	884,857	-103,655	55,909	-28,746
Lignite	kg	-113,577	-174,959	-113,265	-113,631	-120,927	-71,924
Natural gas	kg	-254,147	-246,246	-251,486	-254,611	-273,620	-143,800
Uranium	g	-1,40	0,00	-1,49	-1,49	-1,44	-1,14
Wood	m <sup>3</sup>	-2,913	-3,952	-2,913	-2,913	-3,179	-1,405

## 8 Discussion and conclusions

This study examines the consequences of changing from conventional distribution of automatically generated documents by ordinary mail to electronic distribution using the e-Boks system. The results are not representative for other types of letters, e.g. personal letters, which may have another life cycle and serve different functions than the automatically generated documents.

### 8.1 Environmental consequences

With this limitation, the results demonstrate clearly that there is an environmental benefit of distributing documents electronically. The benefits are unambiguous, applying to all environmental impacts and resource consumption being investigated in the study.

Using the normalised results, the reduction in global warming potential appears to be the most important benefit. The e-Boks system saves the environment for emission of climate gases from the activities of 190 average citizens in Denmark. In absolute figures the savings amount to 1652 tonnes of CO<sub>2</sub>-equivalents.

The reduction in emission of acidifying substances like sulfur dioxide and nitrogen oxides amounts to more than 16 tonnes of SO<sub>2</sub>-equivalents, corresponding to the emissions from the activities of 163 average citizens in Denmark.

The reduction in other types of environmental impacts is not so significant, but there is as mentioned a consistent reduction in all impact categories.

The e-Boks system consumes much less energy than the conventional system, 12,715 GJ compared to 37,768 GJ. This difference corresponds in to about 600 tonnes of Oil Equivalents, a unit used by OECD to combine different types energy consumption in one figure (One tonne Oil Equivalent = 41.868 GJ). As can be seen from Table 9 and Table 14, the savings are mostly related to crude oil (in general used for production of transportation fuels, materials and process heat) and natural gas (in general used for production of materials, heat and electricity).

It is outside the scope of the study to discuss in any detail whether the benefits are large or small. It is however possible and meaningful to conclude that there are no trade-offs associated with the e-Boks system as it is outlined in the system description.

### 8.2 Sensitivity analysis

Care has been exercised in establishing system boundaries which on the one hand gives a picture of the systems which is as precise as possible, and on the other hand ensures that the e-Boks system is not unjustly credited for any benefits, e.g. by choosing in favour of the e-Boks system (or against the conventional system) when such choices have to be made.

The system boundaries of the baseline systems were presented to invited stakeholders at a workshop held in the middle of the project period. The workshop discussed the most important assumptions and gave suggestions for where the use of sensitivity analysis seemed to be appropriate. Following the workshop, four elements were selected for closer examination, i.e.

- Printing frequency
  - What happens with the results if all (or none) of the documents are printed in the e-Boks system?
- Paper end-of-life
  - How important is the assumption that documents of the e-Boks type are disposed of in the same way as the average paper waste from households?
- Viewing time
  - What happens if users extend their viewing time significantly, compared to the 3.25 minutes assumed in the baseline scenario?
- IT equipment
  - How will the use of more energy-efficient IT equipment affect the benefits?

The primary purpose of the sensitivity analysis was thus to ensure that the results of the baseline scenario are robust. Judged from the calculations this seems to be the case, because the rather drastic changes in assumptions do not change the overall picture of unambiguous benefits of the e-Boks system compared to conventional distribution.

### **8.2.1 Viewing time**

The most critical parameter seems to be viewing time. If a user has a relatively slow internet connection or needs to scrutinize all documents then the benefits of electronic distribution are reduced significantly. If 10 minutes is used to view a document, the benefits in form of reduced global warming impact and consumption of energy almost disappear. There are, however, still large benefits in all other impact categories.

In line with this it can be concluded that a shorter viewing time than the 3.25 minutes assumed in the baseline scenario will increase the benefits significantly. As an example, 60-80% of most impacts in the e-Boks system are associated with a viewing time of 3.25 minutes, and if this time can be reduced to e.g. 2.5 minutes, the overall impacts may be reduced by 20%.

Compared to the reduced benefits when a document is printed it seems to be better to print than to extend the viewing time to 10 minutes. There are, however, large differences in the behaviour of individual users, and the only valid recommendations are to "use as little time as possible viewing the documents" and to "print documents only when a hard copy is needed".

### **8.2.2 End-of-life of paper and envelopes**

The end-of-life of paper and envelopes is also important, i.e. whether it is recycled or incinerated with energy recovery. The sensitivity analysis, however, does not provide a uniform picture of whether incineration or recycling is better for the environment. If the amount of paper being incinerated is increased, the benefits in form of less emissions of greenhouse gases seems to decrease, while there are increased benefits from less consumption of fossil fuels and less emissions of acidifying substances.

The results from this sensitivity analysis are highly dependant on the assumptions with respect to both substituted energy from waste incineration on the one hand and paper recycling and paper substitution process on the other hand. The choices made in the present project are judged to be realistic, but given the globalisation of the market for paper waste, the results should be interpreted with great caution.

The general recommendation is therefore to dispose of documents in agreement with the suggestions from relevant local and national authorities.

### **8.2.3 Printing frequency**

Printing a document supplementary to viewing it reduces the environmental benefits with about 40% in all examined impact categories. The reduced benefits occur because of the need for more paper to be produced. When a document is printed, one of the major differences between the electronic distribution and the conventional distribution no longer exist. There is, however, still a significant benefit from using the e-Boks system, and this is mainly attributable to the absence of an envelope in electronic distribution.

e-Boks users should of course print documents that contain information which is important for them to have in hardcopy. The environmental impacts from printing a single document are very small, but as with all other types of consumption it causes an impact on the environment which should be avoided if possible, and especially if the consumption is not necessary. It is therefore suggested that e-Boks increases the information to its customers about the possibilities in the e-Boks system, e.g. that the documents are stored safely until deleted by the user or e-Boks is notified that the user is dead.

### **8.2.4 IT equipment**

Switching to more modern IT equipment appears to increase the benefits of the e-Boks system, at least if the new equipment is more energy efficient. The benefits in the baseline scenario can increase with about 20% for important categories if modern and energy efficient equipment is used consistently in the future. The calculations of the baseline scenario can thus be seen as a conservative approach which may underestimate the benefits in practical life.

## ***8.3 Important features of the examined systems***

The aim of the study is to examine the consequences of changing from conventional to electronic distribution of automatically generated documents, rather than examining the two systems separately in great detail.

The life cycle models used to arrive at the desired output are fairly detailed and it is therefore possible to extract various types of information with a high level of detail. We have, however, chosen to present results at a relatively aggregated level of detail, dividing each of the systems into four core activities. This approach allows the most important processes to be pinpointed and if needed also the possibility of investigating the importance of single elements.

In the present report, only selected findings are reported and summarised in the subsequent sections.

### **8.3.1 The e-Boks system**

The impacts of the e-Boks system are primarily caused by the end users when viewing and printing the documents. These activities account for more than 90% of all impacts, with viewing being most important with respect to global warming potential and consumption of fossil fuels, while the other impacts are more equally distributed between the two activities.

The impacts from central e-Boks activities are small, compared to the impacts caused by the individual users. Storing and handling of the documents at the host (KMD) only accounts for 2-7% of the total impacts, and as outlined in the section on "e-Boks' activities", p. 30, the impacts per document stored are expected to decrease over time because of technological improvements. Transmitting messages and documents from e-Boks to the users is not associated with any significant impact.

The e-Boks system is not yet fully mature, at least not when the behaviour of individual users is considered. Most users probably regard e-Boks as a possibility where it is easy to learn and use the basic features while the more advanced options are not used to a significant extent. If this statement is true, e-Boks can improve the performance of the overall system by offering the users tools which can reduce the time used to view the documents and/or reduce the perceived need to print documents. It is outside the scope of the current project to describe such tools in any detail or to outline how the use of the tools is communicated to the users.

### **8.3.2 The conventional distribution system**

The conventional distribution system was divided into four core activities, which all showed to be of importance in the overall picture.

Production of paper and production of envelopes are most important, accounting for 65-95% of the total impacts in the conventional distribution system. The life cycle of the envelopes appears to be more demanding than the life cycle of the paper, although the envelopes weigh less than the paper used for documents. Paper waste is, however, unavoidably generated in envelope production, which also demands energy for mechanical and electronically processing and printing. Differences in recycling processes may also play a role in the overall picture.

Printing and packing of the documents accounts for 3-16% of the overall impacts. The contribution is primarily related to the electricity consumed in the highly integrated process used today. It is mentioned that the consumption of electricity at the large Danish supplier of printing services used in the present study is significantly smaller (a factor 3-4) than at the printing service used in the Swedish study by Moberg et al., 2008. There is no readily available explanation for this, other than the Danish company for a long time has had focus on reduction of electricity consumption.

Postal services, i.e. distribution by Post Danmark, account for 8-19% of the total impacts, e.g. being responsible for 17% of the consumption of fossil energy and 19% of the emission of greenhouse gases. In line with the consequential LCA approach it has been assumed that only the handling of the documents are affected by a change to electronic distribution, not the infrastructural elements like heating and lighting of buildings. It is, however, obvious that the activities at Post Danmark only play a modest role in the overall picture.

## **8.4 Conclusions**

This study investigates the consequences of changing from conventional distribution of automatically generated documents by ordinary mail to electronic distribution using the e-Boks system. For all assumptions, we have aimed at choosing a conservative approach in favour of the conventional system. Still, the study shows that changing from conventional distribution to the e-Boks system has positive consequences for the environment.

Benefits are observed for all environmental impacts examined, both at the global level (reduced contribution to climate change), the regional level (contribution to e.g. acidification and nutrification) and with respect to total energy consumption.

The benefits (reduction in environmental impacts) are significant, corresponding in the best case (global warming potential) to the yearly impacts caused by 190 average Danish citizens and at least to the impacts caused by 52 average citizens (smog formation). It is, however, also evident that the use of e-Boks is only a small step towards reaching a political goal of a 20% decrease in emission of climate gases by 2020. This decrease corresponds in crude terms to the emission from one million Danish citizens.

It is also concluded that the benefits are achieved in an unambiguous way, i.e. there are no apparent trade-offs. In all examined impact categories the results point towards a benefit, but it must be noted that potential local environmental impacts on human health or ecosystems have not been addressed to any significant extent.

The results are judged to be very robust. A series of sensitivity analyses have been applied in order to investigate worst case with respect to selected elements. Even when worst-case assumptions are applied to these elements there are still benefits from changing to the e-Boks system. The e-Boks system as it is outlined in the system description is thus inherently associated with smaller environmental impacts than the conventional system.

## References

- Ekvall T, Weidema B (2004). System boundaries and input data in consequential life cycle inventory analysis. *Int J LCA* 9(2004) 161-171.
- Frischknecht R, Jungbluth N, Althaus H-J et al. (2007). Overview and Methodology. Ecoinvent report No. 1. Swiss Centre for Life Cycle Inventories, Dübendorf, Switzerland.
- Hauschild M, Wenzel H (1998). Environmental assessment of products. Volume 2: Scientific background. London: Chapman & Hall.
- Hischier R (2007). Life cycle inventories of packagings and graphical papers. Ecoinvent report no. 11. Swiss Centre for Life Cycle Inventories, Dübendorf, CH. Data as implemented in the GaBi4-version of ecoinvent.
- Larsen HF, Hauschild M, Hansen MS (2006). Ecolabelling of printed matter – part II. Life cycle assessment of model sheet fed offset printed matter. Working Report No. 24 2006, Miljøstyrelsen. Downloaded from <http://www2.mst.dk/Udgiv/publications/2006/87-7052-173-5/pdf/87-7052-174-3.pdf>
- Larsen TF (2007). Udbredelse og anvendelse af husholdningsapparater i boligsektoren (p. 168). ELMODEL-Bolig. Datagrundlag 2006. Downloaded from <http://www.elmodelbolig.dk/>, November 2008.
- Moberg Å, Borggren C, Finnveden G, Tyskeng S (2008). Effects of a total change from paper invoicing to electronic invoicing in Sweden. A screening life cycle assessment focusing on greenhouse gas emissions and cumulative energy demand. KTH Centre for Sustainable Communications, Stockholm. (downloaded from <http://www.infra.kth.se/fms/pdf/Moberg%20et%20al%202008.pdf>).
- Rahbar A, Larsen HS, Larsen TF (2008). ELMODEL-Bolig. Nye husholdningsapparaters elforbrug 1970-2206 (p. 78). Downloaded from <http://www.elmodelbolig.dk/>, November 2008.
- Regeringen (the Government) (2003). Affaldsstrategi 2005-08. September 2003. <http://www2.mst.dk/udgiv/publikationer/2003/87-7972-971-1/pdf/87-7972-973-8.pdf>
- Schmidt A, Strömberg K. (2006). Genanvendelse i LCA – systemudvidelse. Miljønyt Nr. 81 2006, Danish Environmental Protection Agency.
- Stranddorf H, Hoffmann L, Schmidt A (2005). Update on impact categories, normalisation and weighting in LCA. Selected EDIP97-data. Environmental Project No. 995, 2005. Danish Environmental Protection Agency.
- TDC (2007). Miljørapport 2006. Download: [http://download.tdc.dk/pub/tdc/om\\_tdc/mennesker\\_samfund/Miljo\\_rapport/Miljoerapport\\_2006.pdf](http://download.tdc.dk/pub/tdc/om_tdc/mennesker_samfund/Miljo_rapport/Miljoerapport_2006.pdf)
- Weidema B (2003). Market information in life cycle assessment. Environmental project No. 863, 2003. Miljøstyrelsen.
- Willum O (2008). Residential ICT related energy consumption which is not registered at the electric meters in the residencies. Willum Consult, June 2008.