# Comparative LCA of a digital invoice versus a paper invoice

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**Abstract** For economic and strategic motive as much as environmental motive, service provider companies are engaged into a transition from paper invoice sent by postmail to digital invoice via Internet. EVEA, with support of EcoInfo Cluster, carried out a comparative life cycle assessment (LCA) of a digital invoice versus a paper invoice. This study was made on behalf of POCHECO, a french company which manufactures and sells envelopes for service providers which need to send invoices to their customers. In this article, the authors present a comprehensive synthesis of this LCA study, from goal, scope, and main assumptions founding the modelling with SimaPro software, to the comparative results. Finally, a discussion about the results is proposed, specially about the main contribution of final customer behavior, and including a brief comparison with Moberg's results [1].

## 1 Introduction

From 2009 to 2010, EVEA with support of CNRS research cluster EcoInfo carried out a comparative LCA study of an electronic invoice versus a usual paper invoice. This study was conducted on behalf of POCHECO company which business is to manufacture envelopes for BtoB customers for enclosing and sending profesionnel mails. Nowadays in this kind of business, a strong trend is to switch from a postal mail service to an electronic mail.

This study shows that in opposition to common thinking, what is too quickly called dematerialization is not always so environmentally friendly. As a non surprising result the outcomes tell us that the global impact of the electronic invoice mainly depends on the customer's behavior about spending time on Internet and printing ratio. Futhermore, for now the comparison between an Internet system and a postmail delivery system is critical and biased because of

the huge uncertainties relating first to ICT systems data and second to user's behavior assumptions. Nevertheless, this issue has further to be tackled because it is probably inescappable that most of the postmail services will switch to electronic services.

# 2 Goal ans scope of the comparative LCA

## *2.1 Goals*

The goal of the study is to compare with a set of 10 indicators the environmental impacts of a paper invoice (PI) and an electronic invoice (EI). The aim of the company is first to define its strategic sustainable way according to environmental specifications (internal goal), and second to communicate according to type III environmental labelling [2] (external goal). In accordance with ISO 14040 guidelines [3], the comparative LCA was submitted to a critical review process.

## *2.2 Boundaries*

For each system a life cycle approach was followed. For the PI system, the life cycle includes the manufacturing of the paper and envelope, the editing process, the sending, the archiving and the end of life. For the EI system the life cycle includes the creation of the invoice, the sending and reception via a Web service and a Web hosting, seeing Internet by user, and finally archiving and end of life.
Buildings, infrastructures, and technological means (such as the "physical" network) were systematically excluded from life cycle inventory (LCI) but their use phase was included if considered as relevant.
Electronic equipments, both industrial or professional and household, included in the EI life cycle are : servers (SMTP 2U, POP 2U, Web 2U), UPS (uninterruptible power supply), air conditioners, computers and laptops, Internet box, household printers.
The following figures 1 and 2 illustrate the boundaries for each modelled system.

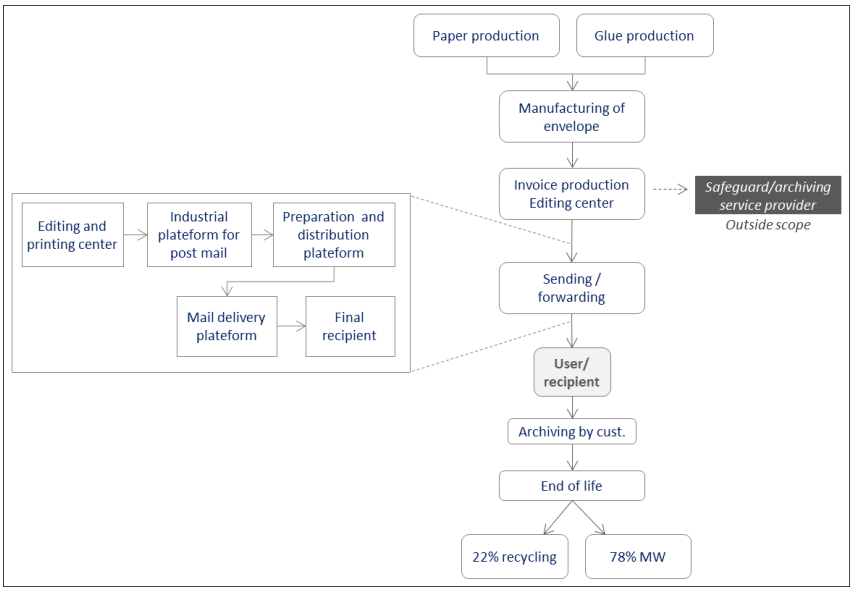


**Fig.1: Life cycle approach for the paper invoice : system boundaries**

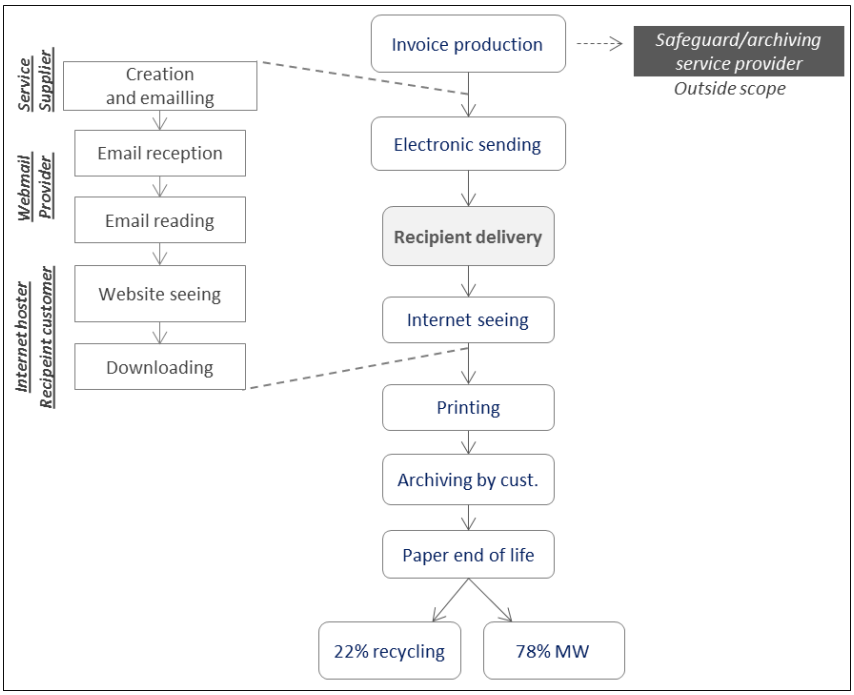


**Fig.2: Life cycle approach for the electronic invoice : system boundaries**

The geographical scope of the study for both systems is France only. That means final customers are located in France. Indeed, though technological systems providing parts of the life cycle can be outside of France (for example, a paper manufacturing factory or a datacenter), this assumption is supported by a short survey within big companies (french phone service companies, energy supplier companies, banks, etc.).

## *2.3 Functional unit*

The functional unit for the comparative LCA is defined as follows :
"To send, receive, view and archive an invoice".
This functional unit includes any type of invoice but the study is supported by a base case scenario which is representative of a phone service invoice that is a two sheets invoice.

## *2.4 Indicators*

The study has been updated at the beginning of 2011 following the critical review process. Indicators used for life cycle impact assessment (LCIA) are listed in tab.1. This selection follows two specifications : first to have a multicriteria environmental representation of the two systems, and second to be compliant as closed as possible to ILCD recommandations [4].

**Tab.1: LCIA indicators for this study**

| Indicators | Unit | Method |
|---|---|---|
| Global warming (100 years) | kg CO2 eq. | IPCC 2007 |
| Energy consumption (non renewable) | MJ | CED 1.08 |
| Abiotic depletion | kg Sb eq. | CML 2.05 |
| Ozone depletion potential | kg CFC-11 eq. | WMO (CML 2.05) |
| Acidification | kg SO2 eq. | CML 2.05 |
| Photochemical ozone creation | kg C2H4 eq. | ReCiPe 1.05 |
| Eutrophication | kg eq. PO43- | ReCiPe 1.05 |
| Human toxicity, non cancer | CTUh | USEtox recommanded + interim 1.01 |
| Human toxicity, cancer | CTUh | |
| Freshwater aquatic ecotoxicity | CTUe | |

# 3 Assumptions and data

The main assumptions underlying the LCA of the two systems are detailled here below.

## *3.1 Paper invoice*

The main assumptions for the PI system concern : the transport stages for the sending process, the archiving material which is modelled as a file made from cardboard and steel, and the end of life of the paper parts (invoice and its envelope). The following table gives hypothesis and figures for the different assumptions.

**Tab.2: Main allocation assumptions for the PI system**

| Stage | Parameters | |
|---|---|---|
| Binder for archiving | Materials : cardboard (75%) and steel (25%)<br>Lifespan : 10 years<br>Capacity : 500 sheets | Allocation / FU :<br>A = 2/(10*500)=4E-4 |
| Transports | The modelled average route is illustrated on fig. 1. | - Light truck : 5 km<br>- Heavy truck (16-32 t) : 300 to 800 km<br>- Car : 1 to 5 km |
| End of life | One part of the paper is collected for recycling and one part is discarded with Municipal Waste (from which one part is incinerated and on part is disposed. | Household paper:<br>- Collection and recycling rate : 22%<br>- Incineration : 41%<br>- Waste disposal : 37% |

### *3.2 Electronic invoice*

The main assumptions for the EI system concern the allocation ratios for the different life cycle equipments allowing to deliver the invoice to final customers. These ratios are of crucial importance for the assessment results. Others assumptions concern the energy consumption and lifespan of the equipments and the end of life scenarios. The following table gives hypothesis and figures for the different assumptions.

**Tab.3: Main allocation assumptions for the EI system**

| Equipment/stage | Lifespan (years) | Energy consumption (Wh/FU) | Allocation ratio (equipment/FU) |
|---|---|---|---|
| SMTP server | 3 | 2.98 | 2.30E-08 |
| POP server | 3 | 3.07 | 2.30E-07 |
| Web server (2U) | 3 | 7.70 | 1.23E-06 |
| Box | 3 | 3.73 | 7.02E-06 |
| Computer/laptop | 4 | 12.26 | 5.27E-06 |
| Network | - | 0.78 | Neglicted |

### *3.3 Data*

LCI data were collected with the aim of being the most accurate and reliable. As far as possible, specific data were prefered. Nevertheless, the most of the data are generic data from Ecoinvent. Some of these generic data have been specified from literature (adapted data). Table 4 here under briefly precises the different kind of data used for modelling.

**Tab.4: Kind of data used for PI and EI systems modelling**

| Kind of data | Application |
|---|---|
| Specific data | Envelope (from POCHECO)<br>Editing center processes<br>End of life of paper (from french MW scenarios) |
| Generic data | Paper sheets for invoice<br>End of life treatments for paper<br>Electronic equipments |
| Adapted data | Electronic equipments and processes<br>End of life processes and scenarios for electronic equipment |

# 4 Modelling

## *4.1 Software and database*

The modelling was carried out with SimaPro 7.2 software and Ecoinvent v2.2 database. Assessment methods are those listed in table 1. For assessment calculation, long term emissions were excluded and infrastrucres were included.

## *4.2 Scenarios*

Both of the two systems can vary a lot depending of some identified parameters. First, the generic word of invoice represents a panel of realities, from 1 sheet to 3 or more sheets (for example for a bank account reporting). Second, specifically for electronic invoice, the environmental impacts depend of Internet seeing time spending, printing ratio, and finally recto/verso printing mode.
We chosen to study some "base case" scenarios with fixed parameters and furthermore we carried out sensitivity analysis about some parameters and assumptions. The following tables 5 and 6 describe the base case scenarios.

**Tab.5: Variable parameters for EI and PI life cycle assessment**

| | Variable parameters | Possible values [unit] |
|---|---|---|
| Paper invoice | Number of sheets | 1, 2, 3 or 4 [sheets] |
| Electronic invoice | Internet seeing time spending | 1, 3, 5, 15, or 30 [min] |
| | Printing ratio | 0, 30, 50, or 100 [%] |
| | Recto/verso printing mode | Recto, or recto/verso [R, RV] |

**Tab.6: Base case scenarios for EI and PI**

| | Base case scenarios according to parameters from table 3 | | |
|---|---|---|---|
| | Definition | | Representation |
| Paper invoice | 2 sheets, recto/verso printing | | A typical phone service provider invoice |
| Electronic invoice | Scenario 1 | 5 min, no printing (0 %) | A final customer, seeing relatively fastly its invoice on Internet and never printing it. |
| | Scenario 2 | 5 min, 30 %, R | A final customer, seeing relatively fastly its invoice on Internet and with |

| | | | |
|---|---|---|---|
| | | | a rather low printing ratio (only recto, being the usual case for households). |
| | Scenario 3 | 3 min, 100 %, RV | A customer or professional downloading its invoice, never reading it on screen but systematically printing it for seeing and archiving. |
| | Scenario 4 | 3 min, 100 %, R | |
| | Scenario 5 | 30 min, no printing (0 %) | A customer taking time for seeing on Internet (rather long time) but never printing. |

For both EI and PI base case scenarios, paper is a 80 g/m2 paper sheet. A sensitivity analysis has been conducted whith this parameter for a 70 g/m2 paper sheet.

# 5 Results

The LCIA results aim at compare environmental impacts of the PI base case with EI scenarios. The relative comparison is shown here under on figure 3 while figure 4 describes some of the quantitative results.
Because comparative figures between PI and EI highly depend of scenarios parameters, conclusions have to be drawn very cautiously. Nervertheless, we can indicate trends in the comparative environmental benefits:

- Results for EI invoice highly depend of the printing ratio (quantity of printed paper and recto-verso mode) and the seeing time on Internet.
- Considering the non renewable energy, it seems that PI is generally a better environmental option except for EI scenarios with a short seeing time and a low printing ratio.
- Considering global warming potential, figures are less contrasted : in numerous cases (which globally represent scenarios with moderate seeing time and low printing ratio), EI seems to be a preferable choice, while for "extreme" scenarios with long seeing time and/or high printing ratio, PI is a better option.
- For human toxicity, ecotoxicity and eutrophication indicators (so for these two last indicators we could say for freshwater pollution) the PI generally appears to be the better option. Nevertheless, we have to keep in mind that toxicity and exotxicity indicators are of huge incertainty.
- Considering the high uncertainty level (mainly for EI scenarios, cf. the discussion on paragraph 6) which leads to consider that figures with a

range of [0-20%] relative difference are approximately equivalent, we could say that EI and PI are equivalent or at less hard to differentiate for "medium" EI scenarios (moderate seeing time and printing ratio) for the most of indicators : abiotic depletion, acidifation, ozone layer depletion, photochemical oxidation and global warming.

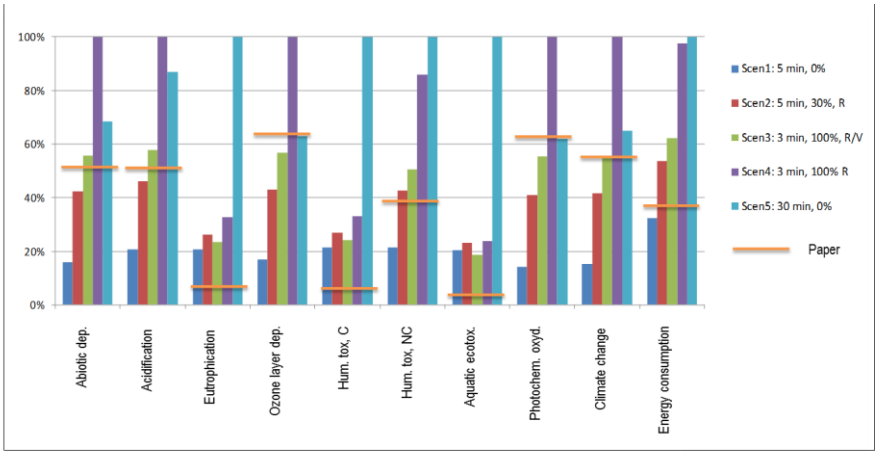


**Fig.3: Comparative LCIA results for PI and EI scenarios**

| Impact Indicator | Unit | PI | EI | | | | |
|---|---|---|---|---|---|---|---|
| | | | S1. 5 min, 0 % | S2. 5 min, 30 %, R | S3. 3 min, 100 %, RV | S4. 3 min, 100 %, V | S5. 30 min, 0 % |
| Abiotic depletion | kg Sb eq. | 1,93E-04 | 5,89E-05 | 1,57E-04 | 2,06E-04 | 3,69E-04 | 2,53E-04 |
| Acidification | kg SO2 eq. | 1,44E-04 | 5,82E-05 | 1,30E-04 | 1,63E-04 | 2,82E-04 | 2,46E-04 |
| Eutrophication | kg P eq. | 1,61E-06 | 4,88E-06 | 6,17E-06 | 5,54E-06 | 7,69E-06 | 2,35E-05 |
| Ozone layer depletion | kg CFC-11 eq. | 3,07E-09 | 8,15E-10 | 2,06E-09 | 2,71E-09 | 4,78E-09 | 3,00E-09 |
| Human toxicity, C | CTUh | 5,69E-10 | 1,94E-09 | 2,43E-09 | 2,19E-09 | 3,00E-09 | 9,08E-09 |
| Human toxicity, NC | CTUh | 4,45E-09 | 2,46E-09 | 4,87E-09 | 5,77E-09 | 9,79E-09 | 1,14E-08 |
| Aquatic ecotoxicity | CTUe | 2,80E-02 | 1,14E-01 | 1,31E-01 | 1,06E-01 | 1,34E-01 | 5,63E-01 |
| Photochemical oxidation | kg C2H4 eq. | 1,41E-04 | 3,19E-05 | 9,21E-05 | 1,24E-04 | 2,24E-04 | 1,39E-04 |
| Climate change | kg CO2 eq. | 3,31E-02 | 9,03E-03 | 2,49E-02 | 3,31E-02 | 5,95E-02 | 3,87E-02 |
| Energy consumption | MJ | 5,74E-01 | 4,84E-01 | 8,03E-01 | 9,34E-01 | 1,47E+00 | 1,50E+00 |

**Fig.4: Quantitative LCIA results for PI and EI scenarios**

### *5.1 Parametric analysis*

The figures for the EI life cycle are highly dependant of two parameters which are the quantity of used paper by final customer (which is determined by ratio printing and/or recto-verso mode) and the time spent on Internet to download and see the invoice. Therefore we carried out parametric analysis with the aim at identify the reverse point comparing EI and PI scenarios. For each printing ratio as indicated on table 5, ie 0, 30, 50 and 100%, we considered several Internet seeing time (1, 3, 5, 15, and 30 min). For each LCIA indicator the figure of the paper scenario gives the reverse point between PI and EI. One example of such an analysis is shown on figures 5 and 6 below for fixed extreme printing ratios of 0% and 100% (for printing mode, a scenario of 60% recto and 40% recto-verso was considered).
These results can be understood as follow : with a 0% printing ratio, the reverse point for global warming benefits is around 20 minutes of EI seeing time. For a 100% printing ratio, even in the favourable case of recto verso printing mode, this reverse point is under 1 minute.

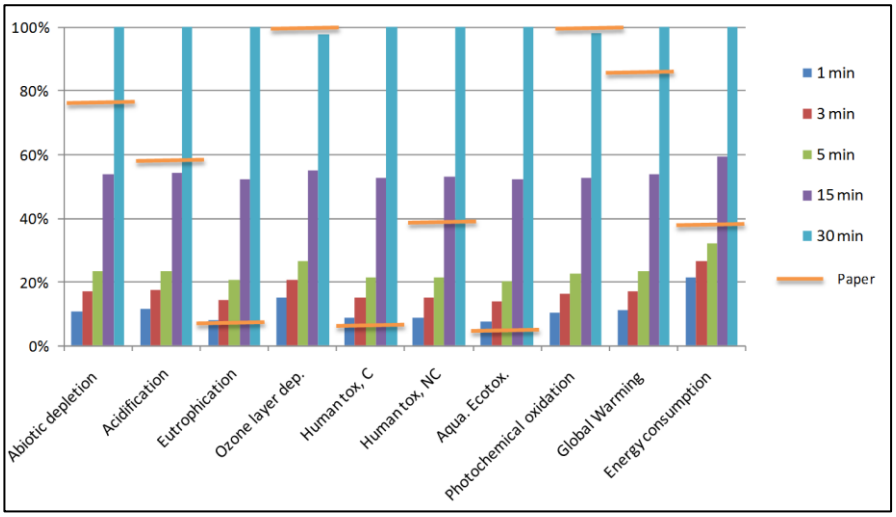


**Fig.5: Parametric analysis with Internet seeing time and printing ratio. Example for 0% printing ratio.**

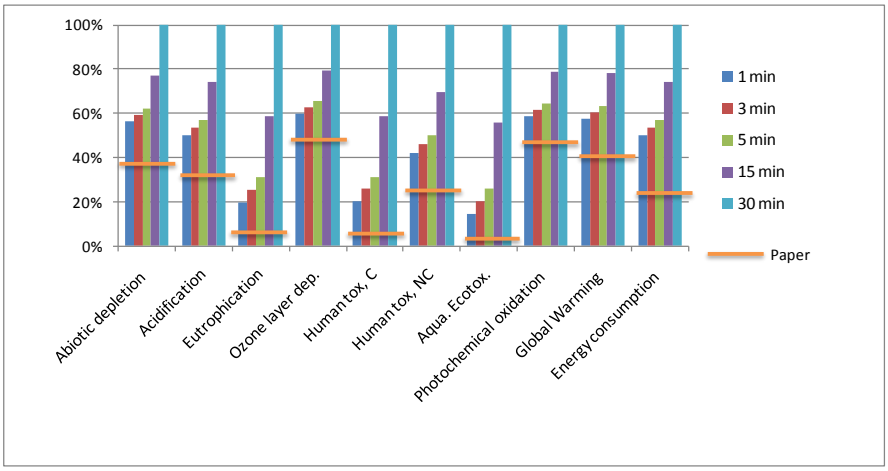


**Fig.6: Parametric analysis with Internet seeing time and printing ratio. Example for 100% printing ratio.**

## 6 Discussion and conclusion

Definitive conclusions about comparative environmental benefits of EI and PI can not be drawn yet. Further investigations need to be performed.

First, limitations of this comparative study have to be recorded. The comparison stands about two technological systems which knowledge degree about data are quite different. From one hand paper scenario is relatively well known with relatively accurate inventory data, and low fluctuating because relatively low dependant of customer's behavior. On the other hand, technological system supporting the digital invoice is quite unknown and unaccurate regarding the LCI data, and furthermore is higly dependant of customer's behavior parameters which are for know highly hypothetical.

Nevertheless we can draw general trends highlighted by this comparative LCA :

- If the final customer never prints its (electronic) invoice, EI seems to be globally a better environmental option (except for water pollution indicators). The limiting factor here is the consulting time. In this case, the reverse point is reached for a rather long time.
- If the final customer systematically prints its invoice, PI seems to be globally a better environmental option.

Finally, as a way to strenghten this results, we can compare it, as far as it is possible, with Moberg's results [1]. This comparison requires some adaptations

from Moberg's results but we can draw this figure : for global warming potential in CO2 eq., with a 0% printing ratio for EI and with a swedish electricity mix (which differs a lot from the french electricity mix), the figure from Moberg's study, expressed as a beneficial gap between EI and PI, is around 30 g CO2 eq per invoice while for the present study and for a similar scenario the gap is around 24 g CO2 eq per invoice. The difference between the two studies seems to be reliant with an explanation about the higher CO2 content of swedish electricity mix. Thus we can conclude that the order of magnitude for global warming is equivalent between the two studies.

Definitive conclusion about comparative environmental benefits depends of customer's behavior and can differ with the considered environmental indicator. In this way, a crucial aspect of the debate relating to this subject is the awareness of the customer concerning the spending time on Internet and the printing ratio and mode. Therefore, from a sustainable point of view, the transition from paper invoicing to digital invoicing has to go with awareness messages to final customer about the way it has to manage its invoices.

## 7 References


[1] Moberg, A., Borggren, C., Finndeven, G. and Tyskeng, S. (2010) "Environmental impacts of electronics invoicing", Progress in Industrial Technology - An International Journal, Vol. 7, No. 2, pp. 93-113.

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