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# Assessing the Carbon Footprint of Paper vs. Electronic Invoicing

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## Abstract

*In this paper, we assess the carbon footprint of paper versus electronic invoicing practices. Based on expert interviews and a case study, we develop process charts for each process (paper vs. electronic, outgoing vs. incoming) and pinpoint the main differences between the paper-based invoicing and electronic invoicing. Our findings indicate that moving from paper-based invoicing to electronic invoicing decreases the carbon footprint of one invoice (lifecycle) by 63%. The greatest effect comes from the elimination of unnecessary manual work, while material and transportation are significant factors as well. This is due to the fact that invoice data in structured, electronic format enables the automation of invoicing in greater extent than paper-based invoicing or electronic invoicing in non-structured format (such as PDF-files). This further underlines the benefits of electronic processing of invoices in addition to the processing cost savings.*

**Keywords: Green IT, carbon footprint, electronic invoicing**

## INTRODUCTION

Climate change is a problem that is now globally recognized. Climate change can be seen as "increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level" (IPCC 2007, p. 30). The amount of green house gas emitted is on the rise. According to the Climate Group, the annual global emissions in 2002 were 40 $GtCO_2e$ and are expected to rise to approximately 53 GtCO2e per year by 2020 (Climate Group 2008, p. 12).

The above facts have lead to a situation where different parties have started to look for solutions. First of all, the discussion has shifted from whether people have caused climate change or not to a debate about an acceptable level of greenhouse gases. The above mentioned level of greenhouse gases in 2020 is estimated to cost "at least 5 % of global gross domestic product (GDP) each year" (Climate Group 2008, p. 12). If corrective action is taken, the loss can be limited to about 1 % of global GDP per year (Climate Group 2008).

Being able to quantify the cost of climate change is driving governments and businesses towards mitigating this risk. Governments and researchers measure the effects on their side and set laws and directives to guide people and businesses. The businesses can either take a proactive or reactive role. In other words, they can either see greening as a business opportunity or simply ensure compliance with legislation. Taking the fierce competition into account, feasible and innovative green solutions are now seen as an important growth opportunity that companies should not miss.

IT plays a significant role in slowing down climate change. The emissions caused by ICT are only about 2%, which is about the same as the emissions of the aviation industry (Gartner 2007). While eliminating inefficiencies within the industry is important, the greater savings will be realized when IT is used as an enabler of more energy efficient and environmentally sound actions (Climate Group 2008). This reflects the dual role of IT. As a matter of fact, sustainability can today be viewed as an essential component of IT. Sustainability posits both tangible and intangible benefits to IT and can be a source of competitive advantage (Schmidt et al. 2009).

One example of such actions is the shift from paper-based invoicing to electronic invoicing. In terms of green IT, paperless actions can be categorized as dematerialization. Recent developments in technology have enabled companies to move from the EDI (electronic data interchange)-based, highly partner-specific, point-to-point interorganizational linkages (IOL) to the open-standard, less partner-specific network models using XML (Zhu et al. 2006). As a result, electronic invoicing is currently being implemented by many European governments and businesses. Electronic invoicing presents a huge potential for decreasing the ecological footprint of business transactions due to the massive volumes. There are around 30 billion invoices that are exchanged between sellers and buyers annually in the European Union, roughly 50% to consumers and 50% between businesses and

government units (see e.g. Billentis 2010; Innopay 2010). Around 90% of invoices are still being exchanged in paper format in EU and the US.

The objective in this paper is to evaluate the carbon footprint of paper invoices and electronic invoices, focusing on business to business invoices. For doing this, we have collected data on the process of handling incoming and outgoing invoices, both in paper-based and electronic invoicing.

The paper is organized as follows. After this introduction, in the second section, we discuss the transition to open-standard interorganizational linkages, more specifically electronic invoicing. We also present the relevant literature on Green IT. In section Three, we discuss the methodological choices taken in the study. In the fourth section, we present the case company and map the electronic invoicing processes and evaluate the environmental effects of these. In the remaining sections, we present the conclusions and avenues for further research.

## LITERATURE ON ELECTRONIC INVOICING AND GREEN IT

### EDI vs. open standard interorganizational linkages (IOL)

The context of this study is the electronic invoicing process. As a concept, electronic invoicing is nothing new. Invoice data was transmitted electronically between trading partners already in the 1970s through EDI systems using proprietary standards. More recently, the Internet, facilitated by the development of open standards such as the TCP/IP and XML, has steadily become a popular platform for interfirm coordination (Shapiro and Varian 1999). Internet-based systems, as exemplars of open-standard IOL, are widely regarded as one of the most significant IOL innovations (Chatterjee et al. 2002). The following table (Table 1) describes the main differences between EDI-based IOL and open-standard IOL (from Zhu et al. 2006).

Table 1. EDI vs open-standard IOL (Zhu et al. 2006)

| | EDI | Internet-based IOL |
|---|---|---|
| | Content platform | |
| Data Standards | Open standards (e.g. ANSI X12, EDIFACT), but less open than XML | Open standards (XML-based standards, ebXML) |
| Complexity | High | Low |
| Customization | Highly partner-specific | Less partner-specific |
| | Delivery Platform | |
| Communication protocols | VAN (private) | Internet (open, TCP/IP based) |
| Interoperability | Low | High |
| Communication costs | High | Low |
| | Trading partner base | |
| Scope | Relatively narrow, with existing partners | Broad, with existing and new partners, hence strong network effects |

In this study, open-standard IOL refers to the ISO 20022, the universal financial industry message scheme which serves as the ISO platform to develop all financial messages. The geographical context of this study is Finland where two XML-based electronic invoicing message descriptions dominate the market for the exchange of electronic invoices using open-standard IOL. These message descriptions are TEAPSSXML developed by Tieto and Finvoice developed by the Federation of Finnish Financial Services.

The importance of electronic invoicing is highlighted by the attention it has received from the European Commission, naming it as one of most important sources of productivity growth in Europe (EEI 2007). Compared to paper-based invoicing or e-mail based PDF-invoicing, electronic invoicing in structured format presents numerous benefits for both trading partners, including processing cost savings, time and material savings, and decreased number of errors in the invoicing process (Lempinen and Penttinen 2009). Despite the

benefits, the transition to electronic invoicing has been slow (Penttinen and Hyytiäinen 2008). As a result, many companies and government units have begun enforcing their suppliers to send their invoices in electronic format (see e.g. Brun 2007; Penttinen and Tuunainen 2009).

In Finland, the geographical context of the study, a company joins the operator-based network (IT operators and banks) for sending and receiving invoices in structured, electronic format. Contrary to EDI linkages which are mainly point to point linkages between two trading partners, the network model and the interoperability between the operators enable the sending and receiving of electronic invoices to all Finnish companies that have joined the network through one electronic invoice operator.

**Green IT**

The concepts of green or sustainable IT or ICT is not yet established, so there are several definitions for it. Initially green IT referred mainly to the energy efficiency of data centres and other equipment. From thereon, more holistic approaches have been taken to include environmental effects in wider scale. While the earliest definitions have used IT or ICT, there is also a call for green information systems, IS, which is entailed to be even more holistic approach.

Green IT or ICT can be defined through its life cycle. Environmentally sustainable ICT can be defined as "the design, production, operation and disposal of ICT and ICT-enabled products and services in a manner that is not harmful and may be positively beneficial to the environment during the course of its whole-of-life (Elliot 2007, p. 107). This view takes into account the fact that the equipment should become less harmful to the environment and that the technology can also be used to do something that creates greater benefit in other industries.

A holistic but yet quite detailed view to green IT is taken in the work of Molla et al. (2009a). According to them, green IT is "a systematic application of environmental sustainability criteria to the design, production, sourcing, use and disposal of the IT technical infrastructure as well as within the human and managerial components of the IT infrastructure in order to reduce IT, business process and supply chain related emissions and waste and improve energy efficiency" (Molla et al. 2009a, p. 4) This view accounts for both technology and the human use of it, of which latter is sometimes excluded from green IT in narrower definitions.

Green IT is a rather new topic in information systems science. The researchers are now adopting the topic on the research agenda, which can be seen as initiation of the discussion in the journals and emerging conference tracks in international conferences. The IS journals are now introducing environment as a topic to be researched. There have been only a handful of green IT or IS articles in the leading journals lately. This is based on the study of Melville (2007) based on the following journals: European Journal of Information Systems, Information Systems Journal, Information Systems Research, Journal of MIS, MIS Quarterly and MIS Quarterly Executive. The emergence of the topic can be seen better in information systems conferences than in the articles. The earliest conference tracks on green IT are from 2007, while this year the topic is present in the most important conferences around the globe.

Environmental business research is conducted and presented in academic journals as well as commercial research and consulting businesses. Regarding the journals, there are there are studies in general journals and journals that concentrate on environmental or sustainable topics alone. Environmental issues are a minority in organizational studies. Between 1998 and 2007, only 6.9% (321 of 4671) of the articles published in leading international management and business journals concentrated on corporate responsibility. Of those, 19% concentrated on environmental issues (Egri and Ralston 2008). The environmentally focussed journals cover some IT related matters. These are IT enabled environmental management systems, EMS, life cycle analyses and environmental certificates such as ISO 14000. While the publishers are not necessarily IT journals, the focus is on the content, not the actual IT.

Commercial research organizations, joint industry associations and non-profit organizations have produced several green IT reports during the past years. Gartner is a technology research organization and Global eSustainability Initiative, GeSI, is a technology industry initiative that became an NGO in 2008 have both produced green IT reports that are widely quoted in media and research. In addition, companies like Accenture and Forrester Research and NGOs such as WWF continuously contribute to the research by looking into specific areas of improvement in IT sector.

Dematerialization, under which electronic invoicing can be categorized, can lead to both improvements in environmental and economic performance. In practice, dematerialization means "substitution of high carbon products and activities with low carbon alternatives, e.g. replacing face-to-face meetings with videoconferencing, or paper with e-billing" (Climate Group 2008, p. 29). While it is widely accepted that digitalizing activities, such as making invoicing electronic, is an opportunity to improve productivity, these activities are an essential component of the low carbon economy. Electronic invoicing is expected to have significantly lower emissions than paper invoicing.

The XML based electronic invoice is an attractive solution to businesses. In a recent study, it was discovered that IT leaders view green IT as a tool to reach cost savings and more environmentally friendly solutions. However, if the savings of a green IT solution are not quantifiable, it can be expected that the adoption rate is lower (Molla et al. 2009b). Since the efficiency improvements, and thus cost savings and emission cuts are quantifiable in case of electronic invoicing, the business case is rather clear from this point of view.

## METHODOLOGY

Our research methodology is case study research. Case study research is especially useful to tackle research questions "how" and "why". The case study is the method of choice when the phenomenon under study is not readily distinguishable from its context (Yin 1994). In our research, we examine the environmental effects of paper-based invoicing and electronic invoicing. Implementing electronic invoicing through open standards in XML format presents a new area of study and, therefore, we find it practical to use the case study approach in our research. Furthermore, we believe that the case under study has revelatory power and can provide new insights on the environmental effects of paper-based invoicing vs. electronic invoicing.

The case approach gives a rich picture and insights through interactions with key players. Key-informant interviewing, structured interviews, and reviews of internal information enabled the researchers to cross-check results from observations and field notes (Sanday 1983). The identification of critical incidents also provides a framework for identifying stages of organizational development (Pettigrew 1985). In our research, we began the study by carefully mapping the process of handling incoming and outgoing invoices in the case company. We asked the interviewees first to describe the process steps and in that way aimed to identify the critical events and issues encountered during the process. This gave us guidance for identifying the relevant issues that were then clarified in the interviews.

Our case company, Finncontainers Oy Ltd, is somewhat new to the field of electronic invoicing in Finland. They have very recently begun sending and receiving electronic invoices. Therefore, we find it fruitful to conduct a case study in this organization that has just implemented electronic invoicing. After having conducted this single case study, our objective is to interview other companies and public organizations to get comparative data on the effects of the implementation of electronic invoicing and electronically transmitting accounting information to customers.

The process charts for paper and electronic invoicing were developed in cooperation with the case company. Three meetings were held to discuss the scope and details of the case. The existing data on processes was presented and discussed at this point. The further communication when developing process charts was done via phone and e-mail.

The starting point for process mapping was the process chart for old, manual invoicing process that the case company already had mapped out. The case company provided us with the process steps, timing of the work based on work study as well as data on energy consumption in the office. The chart was further developed by adding details and mapping the components that generate $CO_2$ emissions. The process for receiving invoices was then composed to reach the same level of details. After that the electronic invoicing, both sending and receival, were mapped including details that allow comparison of the electronic and paper, or manual invoicing processes. The time spent working on the electronic invoices to be implemented are assumed to be about 1/5th of the time spent on manual invoicing. This is an industry estimate.

## CASE ELECTRONIC INVOICING AT FINNCONTAINERS

Finncontainers is a logistics services company, founded in 1996. Its range of services includes logistics services such as container sales, leasing and transportation. The company is one of the biggest container companies in Finland. Finncontainers' turnover in 2008 was 3.4 million Euros. The company's storage facilities are located in the biggest harbor towns in Finland. As a result, the company is able to deliver containers to their customer companies within a few hours of the order.

The company uses modern computer systems to allow for the sales support team to serve the customers effectively and efficiently. One part of this modernization of the information systems is the initiation of electronic invoicing in 2010. Besides efficiency in financial administration processes, another reason for the company to start electronic invoicing was the positive effect on environment. Therefore, the company decided to participate to the study mapping the environmental effects of paper-based vs. electronic invoicing.

All in all, we described four invoice handling processes. These are outgoing manual invoice, outgoing electronic invoice, incoming manual invoice and incoming electronic invoice. The paper invoicing process is here called manual invoicing, indicating that the process expects significant amount of manual work to be done. The processes of sending and receiving an invoice are separated here because these are two separate processes from the viewpoint of the firm.

The scope of the carbon study is the following. We have mapped the invoicing process from the viewpoint of the small and medium sized company. When accounting for the carbon footprint, we have considered the inputs, main process and outputs. The emissions from the whole life cycle are accounted for the paper and envelopes used. Also the carbon footprint of an office worker is calculated in $CO_2e$. Otherwise we have accounted for the emissions caused during the handling of the invoice or disposal of material only.

The outgoing manual, paper based invoicing process, presented in Figure 1, starts with creating the invoice by inserting the data from the order into the invoice form. The details are then checked and when the invoice is ready, two copies are printed out. One invoice is then put into an envelope, franked and taken to a mailbox. The other copy is put into a folder. The mail company then delivers the letter to the receiver. Next the sender retrieves payment details from the Internet bank and matches the payment received to the invoice sent. The accountant operates the accounts receivable, but no specific time is allocated to a single invoice. The invoice paper copy is archived for six years as per Finnish legislation. Then the paper is recycled.

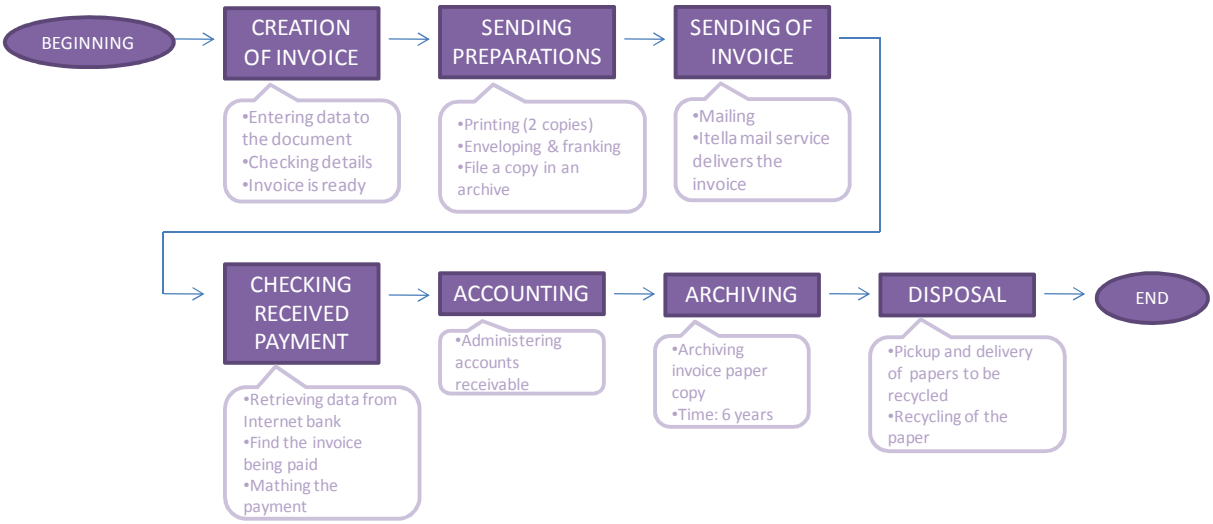


Figure 1: Processing outgoing paper invoice

Every step of the outgoing electronic invoice process, presented in Figure 2, is changed due to automation. During this process, no print copies of the electronic invoice are made. Only sales order data is needed to generate the invoice, where the invoice address acts as an identifier of the recipient. The invoice is then sent to the Internet bank from where the invoice is further sent to the recipient. The sender again retrieves payment data from the Internet bank and matches the payment which has now arrived at their account. The accountant does not need to do any invoice specific manual work since the process is automated. The invoice is archived for six years in electronic format only. The Finnish law states that an invoice can be archived either in paper or electronic format, so we assume no unnecessary paper copy is made. In the case of electronic archiving, two backup copies are required in addition to the original data on the service provider's server. The backup copies are saved on CD ROMs. In the end the old files will be deleted and the CDs disposed as burnable waste.

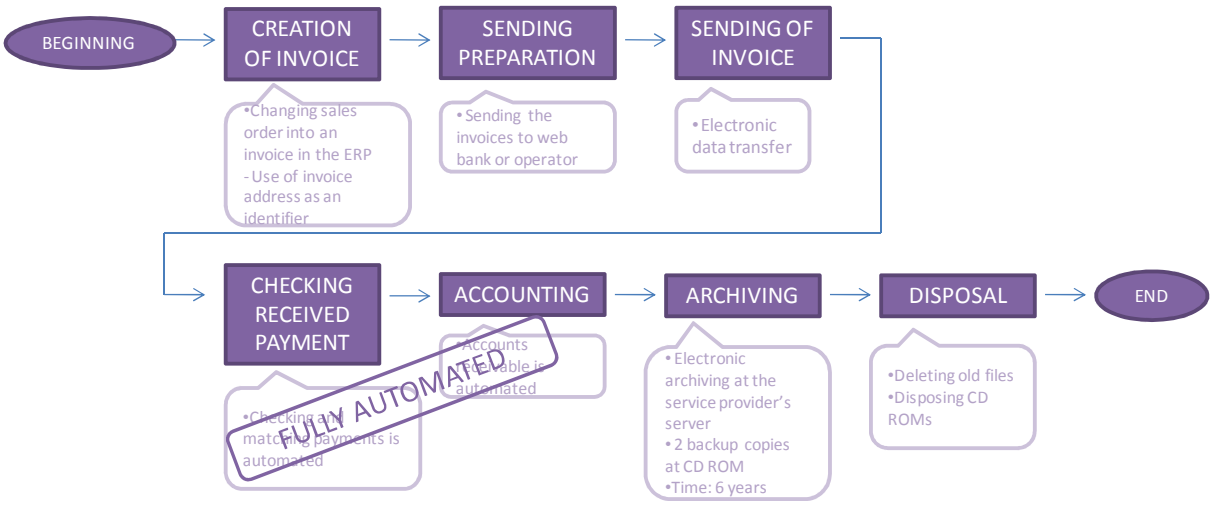


Figure 2: Processing outgoing electronic invoice

The incoming manual invoice process, presented in Figure 3, starts with receiving the invoice letter. The letter is opened and the details checked. Since the case company is a small company, there is no formal approval process. The person who opens the mail verifies the invoice against order details. The invoice is then temporarily archived because the payments are done in batches. The payment is created in the Internet bank. After confirming the payment, the invoice is again put into the archive. The accountant handles accounts payable and creates a monthly income statement. For this purpose, the invoices are sent back and forth between the case company and accountant once a month. The paper invoices are again kept in the archive for six years. The disposal is identical to that of outgoing paper invoices.

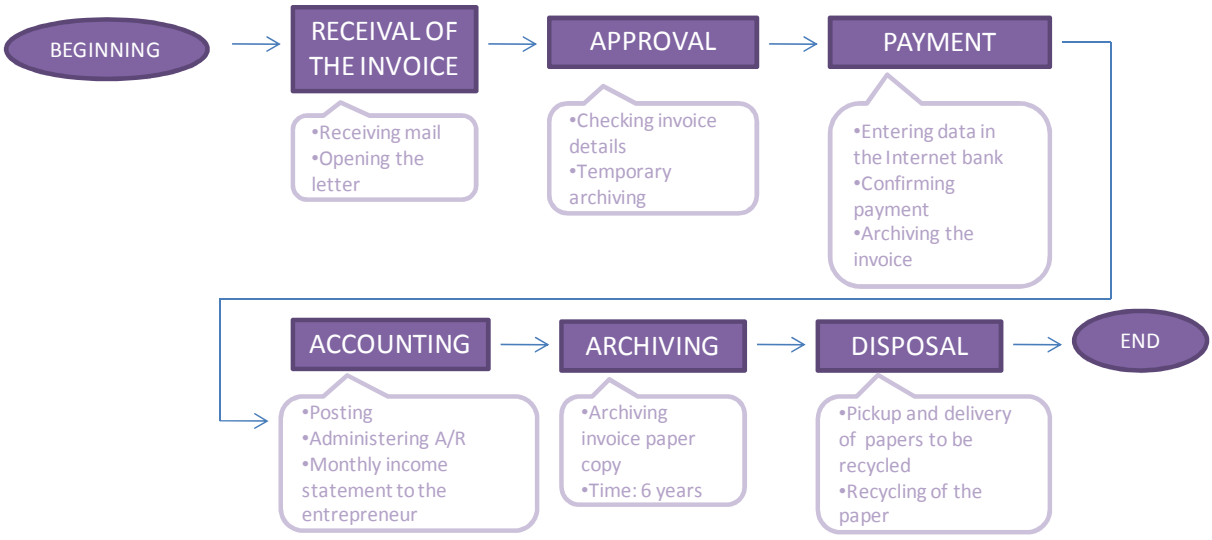


Figure 3: Processing incoming manual invoice

The incoming electronic invoice process, presented in Figure 4, requires changes in each step of the process when compared to the manual process. Similar to the outgoing electronic invoicing, no print copies of documents are made in this case. The receival of the invoice takes place in the Internet bank where the invoices are retrieved. The invoice is then approved by checking the data and the payment is then confirmed. The software in use allows accounting to be automated in this part. Therefore the accountant does not need to process individual invoices anymore. No monthly mailing of documents to the accountant is needed either because the accountant has access to the same programs that the company uses. The electronic archive is kept for six years along with the CD ROM backups. Disposal means deleting old files and disposing CDs as burnable waste.

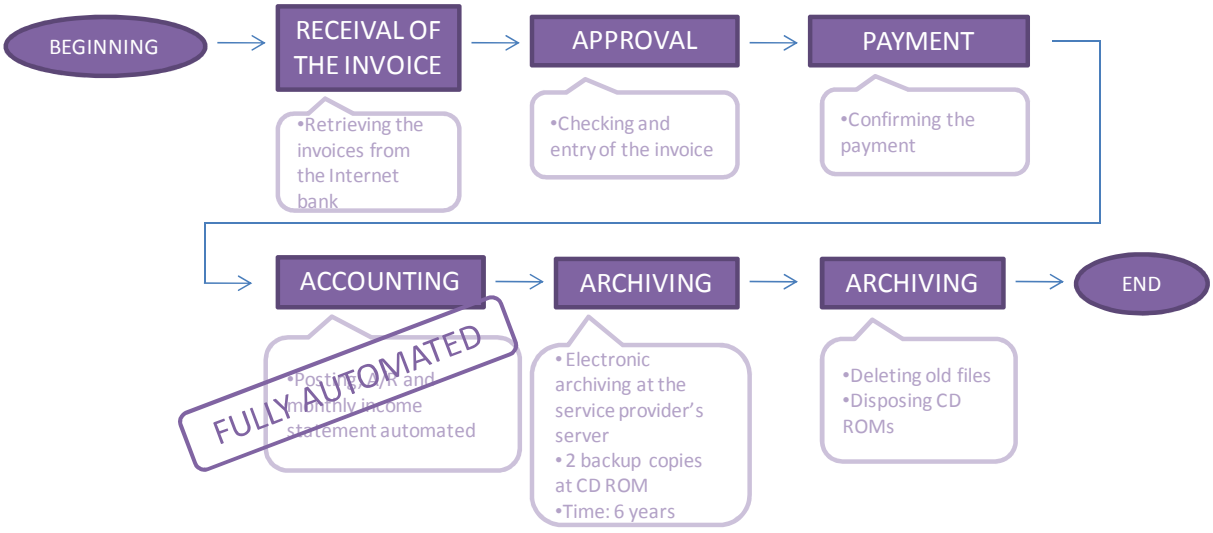


Figure 4: Processing incoming electronic invoice

There are total of eleven components that created the carbon footprint of the invoices in our study. All of this information was gathered from public documents. Printing paper is assumed to weigh 80g/m$^2$, have a regular emissions factor and be recycled as per Finnish policy (Ilmastolaskuri 2005). Since there was no information available on the carbon footprint of envelopes, we assume it is the same as that of the printing paper. The carbon footprint of delivering a letter in is assumed to be 21 g$CO_2$ per invoice (Itella and Natural Interest 2009). The ink used in printing is not accounted for since there were no data available. However, ink is estimated to account for approximately 1 % of carbon emissions of printing (European Printing Ink Association 2007).

The work related emissions are covered with a carbon footprint of an office worker and electricity consumption of additional machinery. The carbon footprint of an office worker in this case is assumed to be 2.89 tonnes of $CO_2$e per year. It includes electricity, heat, garbage, water, materials, business travel and travel to workplace and back home. The figure is the footprint of an office worker in a Finnish public sector office. The figure is somewhat low, but it fits an operative worker's profile well. It is assumed that such operative personnel may use public transportation when travelling to workplace and that he/she does not do business travel. (Ympäristökeskus 2010) Regular machinery like PC and printers assumed to be included in this figure, but the energy consumption of a franking machine is added as a separate component as it is a machine that the case company purchased only because it is needed invoicing. The electricity required by the franking machine, which is assumed to be turned on constantly, is assumed to have a carbon factor of 103 g/kWh (Helsingin Energia 2010).

As per Finnish legislation, the paper invoices are to be archived for six years after which those can be disposed. The case company archives the invoices in a spare room in their office. Thus the carbon footprint from this activity is calculated based on the heat required. The specific emission factor of heating is assumed to have a carbon factor of 96g/kWh (Helsingin Energia 2010). The heating consumption of the premises was calculated using an office building's specific consumption of heat 33,8kWh/rm$^3$ (Motiva 2008). The details on archive space requirements were gathered from the case company.

There are several estimations that are used for electronic archiving and invoice data transfer. Archiving of electronic invoices is accounted for as the energy consumption of transferring the data to the server and keeping it there for six years. The Finnish mail service estimated this to be 2.76 g$CO_2$ per invoice, including server energy consumption and air conditioning requirement using power usage effectiveness, PUE, factor of 2 (Itella and Natural Interest 2009). When archiving, the law requires keeping two backup copies at CD ROMS or other similar format. It is estimated that with the current volumes, the case company would need one CD per year for invoices. Thus, two CD ROMS would be required each year to fill the backup requirement. The emissions are accounted for disposing the CD as burnable waste as per Finnish policy (Ilmastolaskuri 2005). Transferring data in this case accounts for sending an electronic invoice to the receiver. We used the figure 0.02 kWh per invoice for this activity (Moberg et al 2009).

Based on our study, the carbon footprint of an incoming electronic invoice can be over 75% smaller than that of a paper invoice. The reduction in the case of an incoming invoice is 77.12 %. We recorded 214.62 $gCO_2$ for an incoming paper invoice. The corresponding electronic invoice resulted in 48.39 $gCO_2$. Regarding the outgoing paper invoice, our calculations result in a carbon footprint of 336.66 $gCO_2$ for the paper invoice and 154.82 $gCO_2$ for the corresponding electronic invoice. This equals a 54.01% reduction in carbon footprint. The carbon footprint of an invoice life cycle is created by adding up the incoming and outgoing processes. From this viewpoint, moving to electronic invoicing reduces the carbon footprint by 63% of the whole life cycle. The results are summarized in Table 2.

Table 2. Carbon footprint of paper and electronic invoices in $gCO_2$

| | Paper invoice | | Electronic invoice | | Source |
|---|---|---|---|---|---|
| | In-coming | Out-going | In-coming | Out-going | |
| Work by invoice clerk | 152,04 | 269,11 | 45,61 | 152,04 | Ympäristökeskus (2010) |
| Printing paper | - | 30,53 | - | - | Ilmastolaskuri (2005) |
| Envelopes | 0,44 | 15,27 | - | - | Ilmastolaskuri (2005) |
| Franking machine energy consumption | 0,002 | 0,02 | - | - | Case company, Helsingin Energia (2010) |
| Invoice mail delivery | - | 21.00 | - | - | Itella & Natural Interest (2009) |
| Work by accountant | 60,82 | - | - | - | Ympäristökeskus (2010) |
| Shipping of material to accountant & back | 0,60 | - | - | - | Case company, Motiva (2008), Helsingin Energia (2010) |
| Heating of archive room | 0.72 | 0.72 | - | - | Case company, Motiva (2008), Helsingin Energia (2010) |
| Backup CD | - | - | 0,01 | 0,01 | Ilmastolaskuri (2005) |
| Electronic data transfer | | | 0,01 | 0.01 | Moberg, Borggren, Finnveden & Tyskeng (2008) |
| Electronic archiving | - | - | 2.76 | 2.76 | Moberg, Borggren, Finnveden & Tyskeng (2008) |
| TOTAL $gCO_2$ | 214,62 | 336,66 | 48,39 | 154,82 | |

It can be seen that the biggest portion of the carbon footprint comes from the office worker who actually does the invoicing. This clearly indicates that automating otherwise manual work, such as invoice handling, does benefit the environment. Automating the handling of incoming invoices produces greater savings also for the environment, as is often the case with regular productivity increases. The quoted industry average for a paper invoice carbon footprint is 100 g $CO_2$ per invoice (Accountis Europe Ltd 2010), which is noticeably lower than the figures calculated here. It is fair to say that this study accounts for the invoice process at a larger scale than the industry average. Since the office worker's carbon profile in this case can be categorized as low, the carbon footprint of a paper could be even bigger if the office staff had a higher carbon profile.

The next most emitting factors are paper products and mail service. Since these components are eliminated when changing to electronic invoices, the carbon footprint is reduced significantly as well. While shifting to electronic invoicing eliminates and reduces some components, new components are introduced as well. Even though the components specific to electronic invoicing produce only a fraction of the emissions created by manual work, it is still important to acknowledge the existence. It strengthens the argument.

## CONCLUSIONS

In this paper, we set out to explore the environmental effects of the implementation of electronic invoicing. We mapped the invoicing processes and pinpointed the parts that were critical in terms of generating carbon footprint. Our findings suggest that the reduction in manual work and the elimination of the use of paper products

and transportation in invoicing reduces the carbon footprint of invoicing process significantly. According to our findings, the difference is around 63% in favour of the electronic invoice life cycle.

What was surprising from the case study was the fact that the reduction of the manual work needed to process the invoice generated the greatest gains in terms of reducing the carbon footprint. This observation goes hand in hand with the potential productivity gains where the reduction in manual work is the greatest factor. People are, therefore, the most important source of productivity gains as well as carbon footprint.

This study further underlines the environmental benefits of electronic processing of invoices. Adding the green label to electronic invoicing adds to the attractiveness of the solution from the business viewpoint. As a matter of fact, the best green solutions typically resonate well with economic objectives.

This study has several limitations to which we propose the following avenues for further research. First, the paper is based on a single case study, mapping the invoicing processes (incoming/outgoing, manual/electronic) of Finncontainers. Further research could take a more quantitative stance or conduct comparative case studies in companies of different sizes and industries. The types of invoices vary greatly in different industries and it would be interesting to compare the different types of invoices from the point of view of carbon footprint. Second, the carbon footprint could be extracted on even greater detail. Currently it is still difficult to get information about energy consumption of servers and electronic data transfer. Even though these components account for a small part of the invoice carbon footprint, it would be beneficial to study these to promote best practices and efficient data centres. Similarly, linking office specifications to business operations from cost and environmental viewpoints would give valuable information to businesses when justifying office renovations and equipment renovations as well. Third, invoicing is only a sub-process in the purchase to payment or order to cash cycle. Further research could take a more holistic view and evaluate the potential for environmental benefits from the whole cycle of handling request for proposals, orders, order confirmations, invoices, and payment receipts.

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