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Environmental Life Cycle Assessment on Paper and Electronic Billing & Payment System

Junbeum Kim
CREIDD Research Centre on Environmental Studies & Sustainability,
University of Technology of Troyes, France

Serge Rohmer
CREIDD Research Centre on Environmental Studies & Sustainability,
University of Technology of Troyes, France

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Junbeum Kim* and Serge Rohmer

CREIDD Research Centre on Environmental Studies & Sustainability,

University of Technology of Troyes, France

To whom correspondence should be addressed: E-mail: junbeum.kim@utt.fr,

Phone: +33-3-2571-8006; Fax: +33-3-2571-7698;

1. INTRODUCTION

Recent worldwide resource depletion, energy shortage, and global warming caused by energy consumption have been become important issues for national policy and sustainability. In response, many studies are evaluating nation's resource productivity and energy consumption and efficiency. Over the past decade, information and communication technology (ICT) has played a powerful role in reducing resource use and greenhouse gas emissions. Also ICT has further enabled major technological and institutional innovations, such as e-commerce, which has facilitated commerce activity. As the role of ICT increases, previous studies show that it has potential to reduce natural resource use, material intensity, and energy use in systems [1-6]. The SMART 2020 report from the Climate Group and GeSI illustrates that "In the U.S., with feasible policy measures, ICT can enable positive environmental change with 13-22% abatement in CO_2 emissions and gross savings of $140-240 billion from reduced energy use."[7] In spite of many comparison studies, the information and data related to material use and energy consumption in billing and payment systems are yet unclear and not well quantified in the U.S. In this study, by using life cycle assessment (LCA) method, we had a comparison study of paper billing and payment (PBP) with electronic billing and payment (EBP). Our results show how ICT can effect to energy use and environmental impacts, and how business can apply our findings to operate with reduced environment impacts.

2. BILLING AND PAYMENT SYSTEM IN THE U.S.

Currently numerous billing payment methods exist in the U.S., including mail, automatic deduction, internet, and telephone. In the billing and payment system, current customers use two systems; electronic billing and payment system (EBP) and paper billing and payment (PBP) mainly. Figure 1 shows the EBP and PBP system. The EBP system is "the electronic delivery and presentation of financial statements, bills, invoices, and related information sent by a company to its customers" [8]. It is typically focused on business-to-consumer billing and payment. On the other hand, the PBP

is the conventional way customers receive and pay their printed paper format bills via regular mail with their monthly transaction statement.

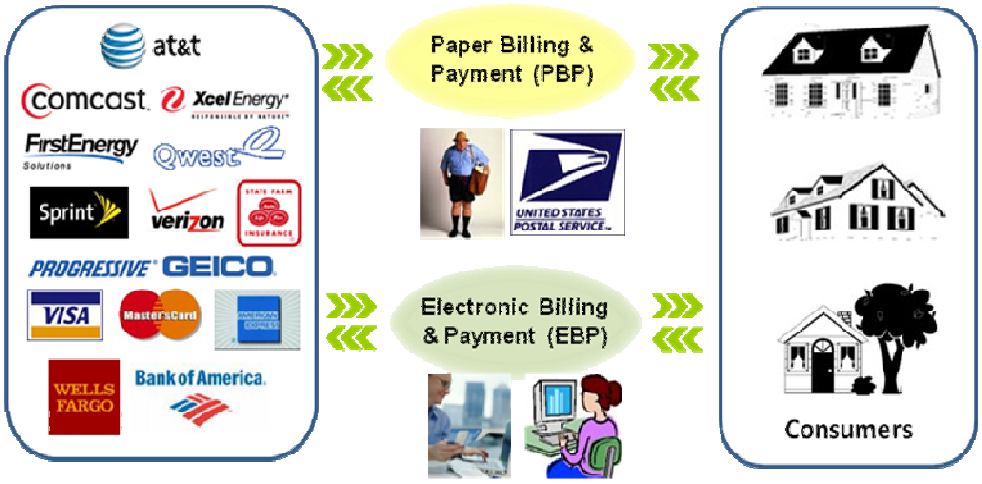


Figure 1. PBP and EBP system in the U.S.

Table 1 shows the average number of bills paid per month and household in the U.S. The portion of the EBP is getting increased from14% in 2006 to 24% in 2009. Meanwhile, the portion of the regular PBP is getting decreased. If this trend continues, the gap between the PBP and EBP will be getting increased.

Table 1. Average number of bills paid per month (household)

Options\Year	2006		2007		2008		2009	
	Average Number of Bills Paid per Month	Share of Bills Paid	Average Number of Bills Paid per Month	Share of Bills Paid	Average Number of Bills Paid per Month	Share of Bills Paid	Average Number of Bills Paid per Month	Share of Bills Paid
Mail (Paper billing)	7.4	63%	7.5	61%	56%	61%	6.3	54%
Automatic deduction	1.3	11%	1.4	11%	11%	11%	1.4	12%
Internet (E-billing)	1.6	14%	1.9	16%	21%	16%	2.8	24%
In-person	0.8	7%	0.7	6%	6%	6%	0.6	5%
Credit card	0.4	3%	0.4	3%	3%	3%	0.3	3%
Telephone	0.3	3%	0.3	2%	2%	2%	0.3	2%
Total	11.8	100%	12.2	100%	100%	100%	11.7	100.0%

Source: HDS Recruiment Sample, FY 2006 through 2009, 2009 Household Diary Study, USPS [9].

3. LIFE CYCLE ASSESSMENT OF THE PBP AND EBP SYSTEM

Our analysis is based on life-cycle approaches for material, energy consumption and environmental impact evaluations of the PBP and EBP system. LCA is "a concept and methodology to evaluate the environmental effects of a product or activity holistically, by analyzing the whole life cycle of a particular product, process, or activity" [10]. As shown in Figure 2, LCA studies analyze the

environmental aspects and potential impacts throughout a product and system's life cycle (e.g., cradle-to-grave) from raw material acquisition through production, use and disposal [11].

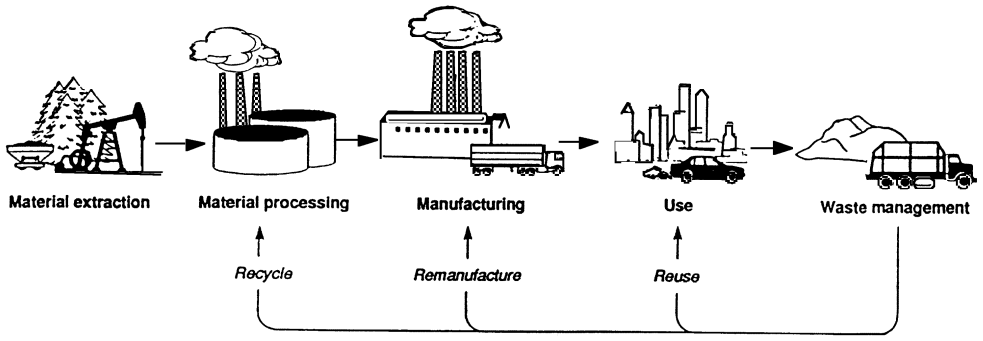


Figure 2. LCA covers the entire supply chain (OTA, 1992 [10])

Using life cycle approaches, environmental impact shifting from one stage of a product life-cycle to another can be better analyzed. Through the use of life cycle approaches in the PBP system, we considered all inputs and outputs from production and operation servers (data center), bill distribution, and computer payments. In the PBP system, production of paper and envelops, production and print of bills, bill distribution (ingoing and outgoing from consumers), payment, and waste were considered. Finally, comparison results between PBP and EBP system in terms of material consumption, greenhouse gas emissions and other environmental impacts are compared in two systems.

3.1 GOAL AND SCOPE

The main goal of this study is to develop a comprehensive life cycle inventory database and to quantify of the potential environmental impacts in life cycle of EBP and PBP system

1) Functional unit

The functional unit is “a measure of the performance of the functional outputs of the product system” [11]. The main purpose of the functional unit is to provide a reference to which the inputs and outputs can be related [11, 12]. The functional unit of this study is defined as “one EBP and PBP billing and payment in the U.S.

2) System boundary

A system boundary is a collection of unit processes by flows intermediate products which perform one or more defined function [11]. Figure 3 shows a schematic diagram of life cycle of two systems.

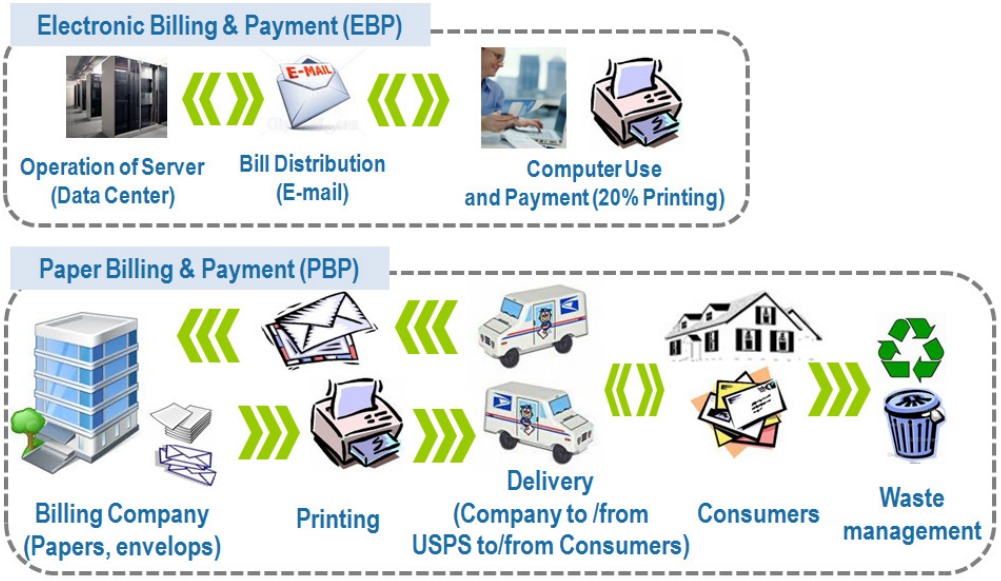


Figure 3. The system boundary of this study

3.2 LIFE CYCLE INVENTORY (LCI)

A life cycle inventory (LCI) is "a process of quantifying energy and raw material requirement, atmospheric emissions, waterborne emission, solid wastes, and other releases for the entire life cycle of a product, process, or activity" [13]. In the LCI analysis, the material and energy flows are listed. This step includes data collection and calculation process to quantify related inputs and outputs in PBP and EBP system.

1) Data and assumptions

: Paper and envelop data, printing data (Ecoinvent database [14])

- a bill paper 4.5g per sheet, a envelope paper weights about 4.3g (own measurement)

: USPS Energy Data (USPS sustainability report [15])

- Energy use (per mail piece) in facilities: 609 GJ/million piece
- Transportation energy data: ~ 0.0036 gallon diesel/piece

: Energy data for server and computer (Ecoinvent database [14])

- Electricity and Gas: 28.8 Wh/bill and 130 J/bill (Data from Telstra [16])
- Computer use: 5.25 Wh (3 mins, A typical desktop computer 80W and LCD monitors 25 W)
  (105W/60 min x 3 min = 5.25, Oxford University Computing Service[17])

: Infrastructure (building and house), server and computer production parts were not considered.

: 2 letter size sheets (8.5 in x 11 in (215.9 mm x 279.4 mm)), Paper basis weight: 4.5g, (72g/m^2)

: Envelope size: #10 Envelopes (4 1/8 in x 9 1/2 in) x 2 (one is for return) [18]

: 20% printing of online bills, no returns (Personal communication information)

: No waste treatment (Personally identifiable information issue)

2) Life cycle inventory for PBP and EBP

Based on data source and assumption for this study, input material and energy data in PBP and EBP system are shown in table 2.

Table 2. Input material and energy for one billing and payment in PBP and EBP sytem

PBP System		data	Unit
Paper production		9.000	g (4.5g * 2 sheets)
Envelope		8.600	g (4.3g * 2 envelops)
Print		9.000	g (4.5g * 2 sheets)
Transport (company to / from USPS)		0.007	gallon gasoline (2 pieces)
Energy use in USPS		0.338	kWh/2 pieces
Transport (USPS to / from home)		0.007	gallon gasoline (2 pieces)
EBP System		**data**	**Unit**
Operation of Server (Data from Telstra)	Electricity	28.8	Wh
	Natural Gas (office)	130.0	J
Bill distribution	Negligible	-	
Computer use at Home	Electricity	5.3	Wh
Paper production (20% of consumers)		0.009	kg
Print (20% of consumers)		0.009	kg

3.3 Life Cycle Impact Assessment (LCIA)

Life Cycle Impact Assessment (LCIA) aims to examine the system from an environmental perspective using impact categories and category indicators connected with the LCI results [19]. In this study, LCIA are assessed with the "Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI)" impact assessment method, which was developed by the U.S. Environmental Protection Agency (EPA) [20]. TRACI facilitates the characterization of environmental stressors that have potential effects, including ozone depletion, global warming, acidification, eutrophication, tropospheric ozone (smog) formation, ecotoxicity, human health criteria–related effects, human health cancer effects, and human health noncancer effects [20]. Through classification and characterization, normalization [21] and weighting [22] stage, according to ISO 14042 [19] and SETAC guideline, we calculated the environmental impact potential for the PBP and EBP system.

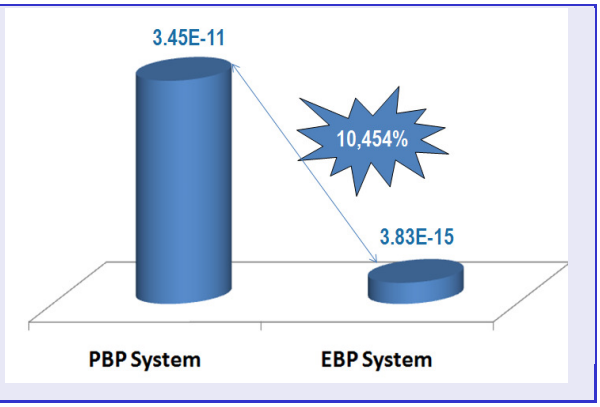
4. RESULTS AND DISCUSSION

1) Weighted result

Table 3 shows the weighted result for PBP and EBP system. As a result, the environmental impact of EBP system is much lower than the PBP system. The main reason for this result is the energy consumption for delivery of billing and payment in PBP system. Among the 9 environmental impact categories, global warming (74%), photochemical oxcidation (12%) and acidification (7%) are the most significant impacts, accounting for about 93% of the total weighted impact. Also in the EBP system, the energy consumption for operation of data server was the main contribution in the total weighted environmental impacts. Among the 9 environmental impact categories, global warming (42%), ecotoxicity (41%) acidification (7%) and are the most significant impacts, accounting for about 90% of the total weighted impact.

Table 3. Weighed result of a billing and payment in PBP and EBP system

Impact Category	PBP	EBP
Global warming	2.55E-11	1.58E-15
Acidification	2.38E-12	2.61E-16
Carcinogenics	4.62E-15	9.86E-18
Non-carcinogenics	8.68E-15	1.77E-17
Respiratory effects, average	1.12E-12	2.82E-16
Eutrophication	7.52E-13	3.59E-17
Ozone depletion	5.68E-16	2.36E-19
Ecotoxicity	7.13E-13	1.55E-15
Photochemical oxidation	4.04E-12	9.09E-17
Total	3.45E-11	3.83E-15



Based on current results of LCA, calibration and validation process on the input material and energy, and allocation method will be considered for the next step of this study. After validation of the LCA, contribution analysis (which inputs make the largest contribution to the environmental impacts) and sensitive analysis will be conducted.

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