Life cycle energy analysis of environmental management reports in the Japanese automotive industry: Learning from the Japanese experience

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Abstract
This paper discusses the assessment and comparison of the life cycle energy impacts of paper-based and electronic environmental reports in the Japanese automotive industry. By January 2007, there were 129 031 ISO 14001 certified organisations and an additional 5389 certified to the European eco-management and audit scheme (EMAS). Energy use and the environmental burdens of environmental reporting by these companies, has grown and can no longer be ignored. Electronic systems are often portrayed as being more environmentally beneficial than traditional ones, for environmental reporting. However there are no known assessment methodologies that address this subject. This paper therefore creates a framework for analysing the two systems. Energy consumption models are developed within a life cycle assessment (LCA) framework and applied to the traditional and electronic systems respectively. A postal system model is developed for energy consumption in traditional mail distribution in Japan under six different scenarios. Data gaps in the Japanese automotive industry are compensated for by the use of justified assumption and sensitivity analysis of the variables concerned. Simulation results are analysed and some decision issues deciphered. A comparative analysis of electronic and traditional environmental reports identifies the necessary preconditions for reducing environmental burdens of the overall environmental management system (EMS).

Keywords: Life cycle energy assessment, electronic and paper-based environmental reporting

1. Introduction

Recently, in response to pressure from various sources like governments, customers, environmental pressure groups, employees and local communities, many companies have set up formal and informal environmental management systems (EMS), the formal systems are being certified to either ISO 14001 standard or to the European Union (EU) Eco-Management and Audit Scheme (EMAS). These systems require adequate communication with all stakeholders. As part communication, organizations have developed annual environmental performance reports. These are paper-based reports distributed upon request. A growing phenomenon is the use of the Internet to disseminate the reports. This substitution of paper-based with electronic communication changes the nature of the environmental impacts that result. These have to do with the dematerialization of information flow through paper replacement, energy use patterns of the two systems, performance changes and transport substitution. However, there is a lack of information on the energy and environmental implications of these two systems and in the absence of analysis, one might think that the use of Information and Communication technology (ICT) in environmental reporting through the Internet uses less energy and hence has less environmental impacts than the paper-based traditional system.

This paper therefore analyses the energy and environmental impacts associated with the distribution of environmental management reports by the Japanese automotive industry for traditional and electronic systems, for different modes of transportation and locations. There are a number of reasons that motivated the choice of this industry. The nine Japanese automobile manufacturers cover a highly representative sample of the industrial sector in Japan that can be well studied. It is one of the leading industrial sectors in the country and worldwide. The other reason is that the country consists of a chain of islands about 3 000 km long, with a full range of the various modes of transportation that includes road, rail air and sea. This enables a more meaningful comparison of various transport modes, related energy requirements and environmental impacts. The focus is on energy consumption because it is a major cause of carbon dioxide emissions, which accounts for most of the greenhouse effect worldwide, contributing to global warming and life threatening climatic changes. The other environmental aspect and impacts have been ignored in this case. The Japanese lessons derived from this assessment can better inform decisions of a similar nature in African countries. Environmental reports detail company efforts, procedures and performance on the environment. They have been extended to cover health and safety issues as well and are in some case called sustainability reports, covering a whole range of social development indicators. A growing number of the reports are published online enabling full accountability to the public and all interested parties.

Ericsson had produced annual environmental management reports since 1992 and these have been transformed to include social and economic dimensions to make them full sustainability reports. ETNO has also produces environmental reports since 1998. (GeSI UNEP, 2002) The questions addressed by this paper are:

- Where are the energy hotspots along the life cycle of paper-based and Internet-based reports?
- What factors are at play and over what range do the variables offer environmental benefits?
- What parallels can be drawn from this study for application to similar systems?

In Japan access to the Internet is very high and this makes electronic transmission viable as a media option. (Japan Statistical Handbook, 2006) The next section models the energy impacts of the two types of reports. This is followed by a discussion of how data was collected and analyzed. The results are then presented and discussed. Sensitivity analyses of all variables are done. A number of conclusions are made on the comparison of the two systems. The conditions under which each one is preferred are indicated.

2. Energy impact analysis: paper-based environmental reports

This section looks at the energy impacts of the dissemination of environmental reports to interested stakeholders using the traditional system of printing the annual report and sending it by normal mail as shown in Figure 1. The postal system on its own is shown later.

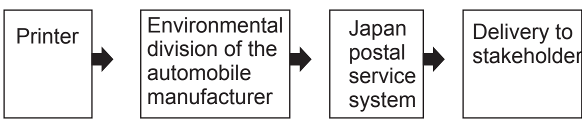

Figure 1: Traditional distribution channel for an annual environmental report

The factors modelled are: Energy use in the production of paper used for the annual reports; Energy use in printing the annual reports; Energy use in buildings used to store the reports; Transportation costs of the annual reports from printers to the automobile manufacturer and from the manufacturer through the postal system to the stakeholder; and Energy use in disposal or recycling of the annual environmental report. The total energy for using the traditional system (*ETRAD*) to disseminate the annual environmental report is given by the following relationship:

$$ETRAD = EP + EPR + ETPC + ES + EPT + ER + ETR \quad (1)$$

Where: *EP* is the lifecycle energy of producing the paper used to make the report; *EPR* is the printing energy of the report; *ETPC* is the energy to transport report from printer to company; E*S* is the storage energy of the report; *EPT* is energy for postal transportation; *ER* is energy used when reading the report at home; and *ETR* is energy to transport report for recycling

The transportation of the report through the postal system is depicted in Figure 2. (Japan's Postal Service, 2002). It is assumed that mail items are taken to a non-collection and delivery post office from where it is transported to a collection and delivery post office in charge of that area. Deliveries are then made in the same area for the first scenario. For the other scenarios, the mail is then sorted according to general area destination and transported to the regional sorting office concerned by a mail truck.

For the second scenario, the mail is sent to the relevant collection and delivery post office for a stakeholder that is in the same region, but in a different area. The mail going to another region is sorted by advanced letter sorters or manually by their addressees' regions. Efficiency in the Japanese Postal System, has been enhanced due to the use of the seven-digit postal code system, which has enabled automation of the sorting process. The sorted mail is out in special containers and transported by mail truck as the third scenario; or by railroad as a fourth scenario; by ship as a fifth scenario; by plane as a sixth scenario; to the regional sorting office of the destination area. Postal personnel and automated machinery sort the mail routing each item to its delivery post office. Here they are further sorted into batches for individual delivery districts. They are finally carried by postal vans, bicycles and motorcycles and delivered to each addressee.

The ordinary collection and delivery post offices provide a service to collect mail at places of business at set times, once in the morning and twice in the afternoon. In addition, they collect mail for entire buildings in bulk when making deliveries. The ordinary collection and delivery post offices provide

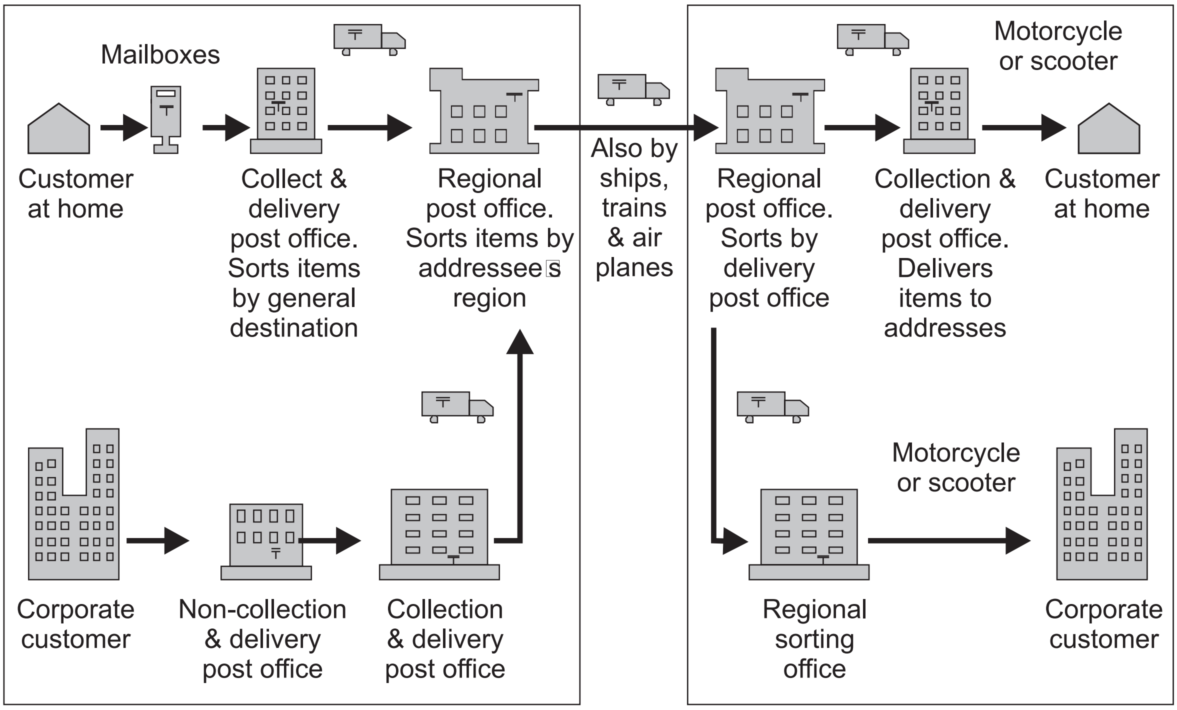

Figure 2: The flow of mail through the Japanese postal system
Source: Japan's Postal Service (2002)

a service to collect mail at places of business at set times, once in the morning and twice in the afternoon. In addition, they collect mails for entire buildings in bulk when making deliveries. This mode of mail collection and delivery is also assumed for the automobile manufacturers.

Inbound and outbound logistics is more balanced and this is done in roundtrip improving the load factor or the fraction of full load that a vehicle carries at any time. The rest of the delivery path is as indicated in the 6 scenarios described earlier. A number of scenarios are therefore considered in the model to evaluate the energy-dependence for distance, mode of transport used and the route taken by the annual environmental report. The situations considered are for delivery of the report to: A stakeholder using the same collection and delivery post office; A stakeholder in the same region, but using a different collection and delivery post office; A stake holder in another region when trunk distances are covered by a truck; A stakeholder in another region when a train is used to carry mail to that region; A stakeholder in another region when a ship is used to carry mail to that region; and Finally a stakeholder in another region when trunk distances are covered by an airplane.

Scenario 1 is shown in Figure 3.

The second scenario 2 is shown in Figure 4. The situation is the same as for scenario 1, except that there is a need for an additional trip between the relevant collect and delivery post offices in the same region.

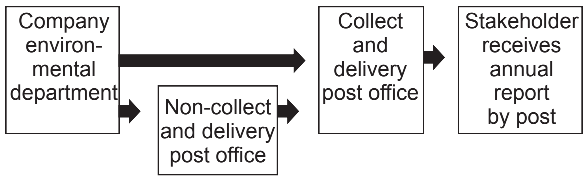

Figure 3: Scenario 1 – annual report movement within the same local area

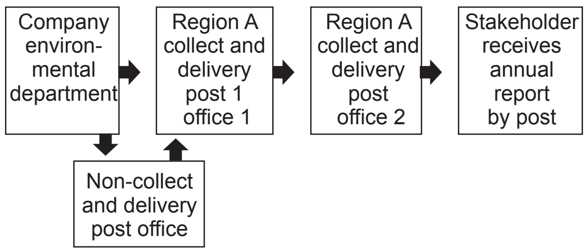

Figure 4: Scenario 2 – annual report movement through the post office within same region

Scenarios 3, 4, 5 and 6 have a similar flow, except that the distances between the regions use different modes as shown in Figure 5.

Furthermore, these scenarios are divided for the case when a company car is used to transport the mail to the nearest post office, which is assumed to be a non-collection and delivery post office and when the nearest collection and delivery post office takes the mail from the office. Annual report requirements outside Japan are not modelled.

General models are used to calculate the energy required to transport the annual reports. The net

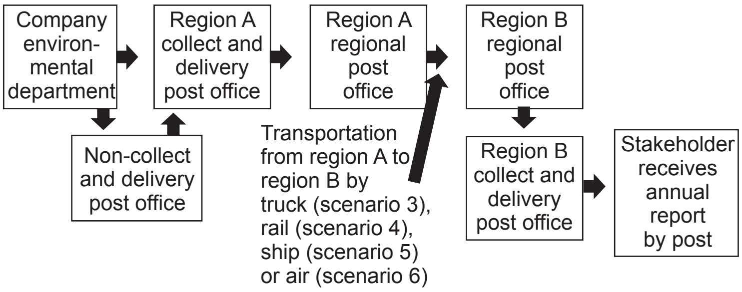

Figure 5: Scenarios 3, 4, 5 and 2 – annual report movement through the post office to another region

weight of the mail is used in all calculations, since it is the cause of the need for transportation. The energy required to transport one annual report using vehicles is therefore given by three different formulations as follows:

$$T = \sum_{i=1}^{i} \frac{D_i}{F_i} E_i \frac{A_i}{M_i} \qquad (1)$$

$$T = \sum_{i=1}^{i} e_j A D_j \qquad (2)$$

$$T = \sum_{i=1}^{i} f_i E_i D_i A \qquad (3)$$

Where the sum is over a number of trip legs i of the distribution path and: T is the transportation energy required used by the vehicle per report in MJ per annual report; D_i is the distance covered in kilometres; F_i is the vehicle fuel efficiency in kilometres per litre; E_i is the energy content of the fuel used in MJ per litre; A is the mass of the annual report in tons; M_i is the total mass carried in tons during leg i; e_i is the energy consumption per ton-kilometre for the train, ship or airplane; f_i is the fuel consumption per ton-kilometre of the transportation mode.

The formulation of the model for transportation for the train, ship or airplane in equation (3) is slightly different because data for these modes exist in the form MJ per ton-kilometre. Similarly, the formulation of the model for transportation by diesel-powered trains, diesel-powered ships or jet oil-powered airplanes can also be expressed in a different way since most of the fuel coefficients for these modes can be expressed per ton-kilometre.

3. Energy impact analysis electronic annual environmental reports

The electronic system is depicted pictorially in Figure 6. The total energy used for the electronic system (EELECT) is given by:

EELECT = EPS + ESU + ESS + EHCU + NE (2)

Where: EPS is the portion of the energy required to produce a server allocated to each report; ESU is energy consumed by the server in the use-phase of the report; EHCU is the portion of the energy used at home surfing the Internet and by the computer during production and use phases allocated to the report; ESS is the energy used in the building where the server is stored during the browsing time; and EN is energy used by the computer and telecommunications network.

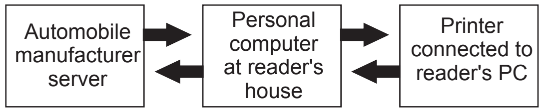

Figure 6: Annual environmental report distribution through the Internet

4. Data gathering and analyses for traditional system

Table 1 shows the number of employees and the number of pages and storage file sizes of the annual environmental management reports for the nine Japanese automobile manufacturers.

By the end of May 2002, Toyota Motor Corporation had distributed 20 000 copies of the Japanese version and 9 000 copies of the English version of the year 2001 environmental report to stakeholders including affiliated companies, suppliers, customers, communities, shareholders and investors. Internet hits averaged 5 200 per month or over 62 000 per year, giving it a total access of at most 91 000 people (Toyota, 2001). This shows that there is a high demand for the reports, which can result in higher demand for paper and energy. The number of reports distributed per company averaged 10 400 per automotive company.

4.1 Energy use in paper production EP

The paper industry is one of the most energy and resource intensive industries. For each ton of paper avoided, CO_2 savings are 3.3 metric tons for newspapers and 3.8 metric tons for office paper (Cohen, 2002). Roughly 29.54 mega-joules (MJ) are required to make 1 kg of packaging paper (DEQ). Other estimates put the electricity consumption of paper production at 10 785 kWh per ton (38.83 MJ per kg) implying that when other forms of energy

Table 1: Characteristics of the 2002 annual EMS reports for the automotive industry in Japan
Sources: Daihatsu, Honda, Isuzu, Mazda, Mitsubishi, Nissan, Subaru- Fuji, Suzuki and Toyota 2002 reports

Name of company (employees)	Number of pages (weight)	PDF file size (MB)	Reports distributed (internet hits/month)
Daihatsu Motor Corporation (11 427)	56 (196 g)	3.600	6 000
Honda Motor Company (28 500)	62 (230 g)	2.080	5 000
Isuzu Motors (11 226)	30 (142 g)	2.180	7 050
Mazda Motor Corporation (19 948)	54 (184 g)	9.660	-
Mitsubishi Motors Corporation (18 498)	82 (332 g)	3.211	2 800
Nissan Motor Company Limited (30 365)	65 (236 g)	1.800	15 000
Subaru – Fuji Heavy Industries Limited (14 601)	62 (227 g)	4.800	8000
Suzuki Motor Corporation (14 260)	56 pages (206 g)	-	-
Toyota Motor Corporation (66 828)	74 (250 g)	15.200	29 000 (5 200)
Total (215 653)	Average 60 (223g)		72 850

are considered paper production consumes more energy. This comes down to about 24 MJ of electricity per kg for recycled paper.

The difference in energy use per ton of paper produced is due to the fact that the first average use is for the packaging paper. Earth Systems (2001) estimates the energy required for producing one ton of paper from virgin wood pulp at 16 320 kWh (58.75 MJ per kg) and that required for producing a ton from waste paper at 5 919 kWh (21.3 MJ per kg). Williams et al (2002) quoting data from the BUWAL database quote the energy to produce cardboard packaging boxes form waste paper at 24-44 MJ depending on the process. For the manufacture of more refined printing paper, the value provided by Earth Systems (2001) is closer to the expected value. The life cycle energy for printing paper from virgin wood is therefore taken as 60 MJ per kg and that for recycled paper is taken as 40 MJ per kg. All car manufacturers studied indicated that they used recycled paper for the annual environmental management reports. As can be seen in Table 5.2, the weight of the annual environmental reports varied from 142 g to 332 kg including the A4 envelopes used, averaging 223 g. The estimated life cycle energy of the paper used to make the reports is therefore estimated as varying from 8.52 MJ to 19.92 MJ with an average of 13.38 MJ for paper from virgin wood pulp and 5.68 MJ to 13.28 MJ with an average of 8.92 MJ for recycled paper.

4.2 Energy use in printing report EPR

The energy to print annual environmental reports is considered. The Environmental Protection Agency of the United States estimates that a conventional laser printer operating for 9 hours a day throughout the year consumes 185 kWh (666 MJ), assuming average power consumption of 56 W. (EPA) An investigation on desktop printers identified that an Epson printer EPL-6100L monochrome laser printer that can print 16 pages per minute and has a maximum power consumption of 720 W, assuming normal printing each page can be printed in 3.75 second consuming 2.7 kJ. Another printer considered was a Brother product, HL-1070 laser printer that can print 10 pages per minute. The warm up time and first page print time combined together is 45 seconds, with a resolution of up to 1200 x 600 dpi and a printing power consumption of 280 W. The standby power consumption is 60 W and the sleep power consumption is 13 W (Brother Europe). Printing each page takes an average of 6 seconds consuming 1.68 kJ.

Ink jet printers consume less energy. However commercial printers for publications are bigger, more powerful and can print colours/pictures, which demand more energy. The total print time depends on image complexity, image size, type of port used and network traffic, printer's memory configuration, print/quality mode selected, colour/correction mode selected, whether or not image smoothing is activated, and number of non-resident fonts used.

Most colour printers are specified at 16 pages per minute black and white and 5 pages per minute full colour. This has been done for a Phaser 750 Xerox colour printer rated at 380 W (Phaser 750). Taking 12 seconds to print a colour page gives an energy consumption of 4.56 kJ per page. Many annual reports in the Japanese automobile industry are very colourful and the average energy consumption per page of the annual environmental report is taken as 3 kJ per page. The number of pages of the annual reports varied between 30 pages for Isuzu Motors and 82 pages for Mitsubishi Motors Corporation. Printing energy consumption per annual report using the above data varies between 0.09 MJ and 0.246 MJ. The average report is 60 pages consuming 0.18 MJ for printing. The life cycle energy use of the printer is ignored because the pages printed are very few and their allocation of the life cycle energy is very small.

4.3 Transportation from printer to automotive company ETPC

Initial transportation is from the printer. A situation at Toyota where data on reports was made available show that paper-based annual reports distributed numbered 29 000 in 2001 and 27 000 in 2002. Assuming that there are still copies available the total number of reports produced is assumed to be 30 000 weighing 7.5 tons. These are brought in by a 10 ton-truck, from a printer 50 km away. This yields a value of 0.03MJ per report.

4.4 Energy use to store report ES

There have been estimates based on input-output models that estimate the energy consumption by stores at 1.1 MJ per book sold in Japan. (Williams et al, 2002)) It is assumed that the storage of the annual report at the offices of automotive company consumes a similar amount of energy per annual report, which is similar to a book.

4.5 Energy use in transporting reporting the postal system

According to the Japan Postal Services, there is on average, a post office every 1.1 km in Japan, distributed in the country's 3 218 municipalities. In the year 2001, the Japanese postal services handled 26.725 billion mail items. Of this, about 26.627 billion items were domestic mail. (Japan's Postal Service2002) There were 24 773 post offices, made up of ordinary post offices, special post offices and postal agencies. These are further split into 4 884 collection and delivery post offices and 15 358 non-collection and delivery post offices and the rest are postal agencies. There were 178 160 mailboxes.

In the year 2000, about 76 million pieces were delivered to approximately 31 million locations daily (Japan's postal Service, 2002). This is about 3 068 pieces per post office per day. The vehicle fleet in 2001 consisted of 82 228 motorcycles and motor scooters; 14 441 compact cars, 9 797 bicycles and 801 compact trucks. Since the post offices do not measure the mass carried per trip, this information was used to estimate the mass of mail carried for various transportation modes. This considered the fact that each mail item could pass through anywhere between one and five post offices. Based on the fact that the total area of Japan is 377 835 square kilometres, the average distance to a collect and delivery post office is 2.5 km. It is calculated by taking the area of the country divided by the number of collect and delivery post offices and assuming a circular area of jurisdiction, and determining half the radius of the circle as the average distance to the post office. This data is also used to estimate transport distances assumed between regional post offices.

The model assumes delivery to homes using motorcycles and collection and delivery to companies using small trucks or compact cars. Some of the vehicles are hired on contract and some parts of collection, transportation and delivery of mail are outsourced to commercial carriers in accordance with the Postal and the Mail Transport Contract Law using competitive contracting. Transportation is by rail containers, ships, vehicles and airplanes. Of the total volume of mail, the percentage handled by external contractors is 21% for collection, 100% for transportation and about 21% for parcel delivery.

In April 2002, the number of contractors was 107 carriers using trucks, 9 airlines and air forwarders, 24 forwarders using railroad containers and 67 shipping companies. Transportation between regional post offices is normally by 10-ton contracted trucks. This information is also used for assumptions made later on mail handling. Energy use in the production of vehicles and fuel is incorporated using a factor of 1.18 in the model, since some studies have indicated that energy to produce fuel is 13% of its energy content and the production phase of a truck, accounts for 5 % of its operational cycle energy use. (Williams et al, 2002) A factor of 1.14 is assumed for the train, ship and for the airplane. The energy content of fuel is given as 5.253 British Thermal Units (Btu) per barrel for gasoline, 5.825 Btu for diesel and 5.670 Btu for jet fuel-kerosene type (EPA, 2001). This converts to 34.86 MJ per litre of gasoline, 38.66 MJ per litre of diesel and 37.63MJ per litre of jet fuel-kerosene type, converting one Btu as 1055 joules and one barrel as 42 United States gallons or 158.97 litres.

4.5.1 Scenario 1

This is the case where the annual report is ether taken to a non-collect and delivery post office 1.1 km away by a 10 km/L gasoline powered company car carrying 10 kg mail and parcels or collected by a postal services van and transferred to a collect and delivery post by a one-ton diesel truck over an average distance of 5 km with a fuel consumption of 8 km/L carrying an average 200 kg, double the average distance travelled to the next such post office and then delivered to the stakeholder using a gasoline 90 cc motor cycle with a consumption rate of 35 km/L over an average distance of 20 km based on the assumption that the round trip of a delivery cycle covers 40 km start and stop carrying an average of 20 kg. This is based on the fact that post office deliveries are done three times a day, once in the morning and twice in the afternoon and the fact that collections are done during delivery as well. For the other case, the assumption is that a small gasoline van 660 cc collects mail in a roundtrip carrying an average of 30 kg. Mail is bulky hence the size of the vehicle used depends on the volume needed and not on the tonnage. The results show that a total of 0.49 MJ is needed when a company sends mail to a non-collect and delivery post office and 0.43 MJ when a collect and deliver post office collects the mail from the motor company.

4.5.2 Scenario 2

In each of the 47 prefectures of Japan, the average distance between such post offices within a prefecture is taken as 50 km, using a 1-ton diesel van, fuel consumption 8km/L and an average load of 400 kg. Corresponding total energy values become 0.64 MJ and 0.58 MJ.

4.5.3 Scenarios 3, 4, 5 and 6

In this case, the average distance to the regional post office is determined on the basis that there are 47 prefectures and one regional post office per prefecture. The average distance to and from a regional post office is taken as 50 km for all regions, in this case for regions A and B. However, a 6-ton truck is used carrying an average weight of 1000 kg. It is assumed that a 10-ton truck is used for transportation from one region to the other, carrying an average 2000 kg of mails and parcels. Transportation energy use for scenario 3 is 1.38 MJ, when a company car transports mail to the nearest post office and 1.32 MJ when the post office collects the mail.

The carbon dioxide emission for Japan Railways Cargo is given as 21.7 g-CO_2 per ton-kilometre. This is based on the Institution for Transport Policy Studies in Japan (Toyota, 2001). On the other hand, the carbon content of distillate fuel or diesel is given as 19.95 Tg Carbon per QBtu, where Tg is teragrams or 10^{12} grams and QBtu is a unit also referred to as a 'Quad', which is one quadrillion Btu or 10^{15} Btu. Similarly 1 TJ is equivalent to 947.8 million Btus (EPA, 2001). This works out to a carbon content of 18.91 g Carbon/MJ or a Carbon Dioxide content of 69.34 g-CO_2/MJ of diesel. This implies that the average consumption of diesel by a train is 0.31 MJ per ton-kilometre. Since very litre of diesel contains 38.66 MJ, fuel consumption is 8.1 millilitres per ton-km. The energy constant of 0.31 MJ per ton-kilometre, is used in the model for the train. The respective results for scenario 4 are 0.82 MJ for own transport and 0.76 MJ for mail collection by the post office. Similarly, the carbon dioxide emissions for a coastal service ship are given as 35.6 g-CO_2 /ton-kilometre. Using the diesel figures above, the average diesel consumption is 0.51 MJ per ton-kilometre and this is taken as the energy coefficient for coastal shipping in Japan. The Scenario 5 results indicate values of 0.84 MJ for a company that drives to the post office to send the report and 0.78 MJ for post office mail collection.

The jet fuel Carbon content coefficient is given by 19.33 Tg Carbon/Qbtu. This translates to 67.18 g Carbon Dioxide/MJ of jet fuel. A survey for transport energy has put the airline energy use at 1.66 MJ and emissions at 110 g-CO_2 per passenger-kilometre in Japan. This is compared against 0.34 MJ and 15 g-CO_2 / passenger-kilometre for Japan Railways East (JR East, 2002). The lower railway value indicates the use of electricity-powered trains mainly as opposed to purely diesel-powered ones. An estimation of the energy per ton-kilometre covered by an airplane can be estimated by assuming the average weight of a person in Japan. On the other hand, Japan airlines has a fleet whose fuel efficiency varies between 1.76 x 10^{-2} and 2.71 x 10-2 kg fuel/seat-km. The CO_2 emissions are for the year 2000 and have been averaged at 806 g per available ton-km (JAL, 2001).

The available seat kilometre is defined as the number of seats provided times the distance of the route in kilometres. The available ton-kilometre is the product of the available mass of each route segment times the distance of the route in kilometres, where the available mass is defined as the number of seats times the standard unit weight per seat (72.5 kg for international routes and 65.8 kg for domestic routes in Japan, plus cargo capacity in weight). This is calculated at 160 kg per cubic meter. The fuel consumption in litres per available ton-kilometre for Japan Airlines dropped from 0.345 in 1999 to 0.327 in year 2000. The target is to reduce it to 0.3105 by the year 2010 (JAL, 2001).

The most important measure for this analysis is the revenue ton-kilometre, which is the weight of revenue passengers, cargo, and baggage and mail times the distance of the route in kilometres. For the year ended 31st March 2001, Japan Airlines covered 12 862 million revenue ton-km out of 18 579 million available ton-km (JAL, 2001). This gives an overall revenue load factor of 69.23%. This is the ration of revenue ton-km to available ton-km. The real fuel consumption rate for the year 2000 is therefore 0.47 litres per revenue ton-km. This is the value that was used in the model in equation 3. This yields values of 2.36 MJ when a company delivers mail to the post office and 2.30 MJ for collected mail.

4.6 Energy use reading report at home

The assumption is that when the stakeholder reads the annual environmental report at home, the purpose of being in the room is to read this report only. This is a worst case scenario, which has been moderated by sensitivity analysis. Lighting of the room takes 100 W if incandescent lighting is used, 25 W if fluorescent tubes are used and 50 W if halogen lamps are used. A worst-case scenario is assumed and 100 W is taken as the power for lighting.

Annual household energy consumption for climatic control is taken as 14.250 MJ (Williams et al, 2002). 900 W per household is the power consumption, assuming that usage is for 365 days, 12 hours a day. Assuming an average of 3 rooms per household, power consumption per room is 300 W. Assuming that the user reads the report online for a total of 2 hours, the energy consumed at home reading a paper-based report is 2.88 MJ.

4.7 Energy use in end of life activities

It is assumed that the paper report is transported to a recycling centre 50 km away by a 6-ton truck, fuel consumption is 3 km/litre, carrying an average 3 tons of used paper. A value of 0.05 MJ is obtained. The summary of data sets used for the inventory analysis of the traditional system is shown in Table 2.

5 Energy analysis for an electronic system

5.1 Energy contribution from production and delivery lifecycle of the server EPS

Assuming that a PC is used as a server, the life cycle energy consumption for the production and delivery of a PC can be considered. This consists of the energy use to produce one computer, which has been quoted at 8.300 MJ (Williams et al, 2002). Some authors have had lower estimates for computer manufacturing and delivery. They have estimated the production and supply chain cycles for desktop computers at 6 004 MJ using the traditional model, 5 823 MJ using the integrated model with air shipping and 5 320 MJ using the integrated model with ground shipping. The use of information and communication technologies in integrating business to business (B2B) and business to customer (B2C) e-commerce results in 3% energy savings if delivered by truck and 11% if delivered by air. (Cohen, 2001) Others have given higher estimates of between 10 and 12 GJ (Herring, 2001).

It is assumed in this case that the server is a bigger computer, whose production and delivery life cycle energy use is 8 300 MJ. A small part of the server is used for the environmental management report. The sizes of the environmental reports, mostly in pdf format for the automobile producing companies in Japan are shown in Table 5.2. It is noted that the environmental report occupies a fraction of the computer and the rest of the use disk space contains other files and websites. For simplicity, the total capacity of the files stored on the server is taken as 40 gigabytes (GB) covering various aspects like marketing, company profile, specifications of other models, newsletters and other functions of the company on the website.

The largest 2002 annual report in terms of file size as shown in Table 4 is by Toyota occupying 15.2 megabytes (MB). It is assumed that double this size is the maximum possible space dedicated for the full environmental report and separated parts of the reports for easier printing by the stakeholder.

Table 2: Data sets used for inventory analysis of the traditional system

Process or aspect	*Data source*	*Values and comments*
Paper production life cycle energy	BULWAL database, Williams et al 2002 and Earth Systems Website	30-60 MJ/kg. Lowest values for recycled paper and highest values for office paper from virgin wood
Paper CO_2 emissions	Cohen, 2002	3.3 tons CO_2 per ton of newsprint paper, 3.8 ton CO_2 per ton of office paper
Power consumption of printer for various modes	USA Environmental Protection Agency (EPA), Epson and Brother	230-720 W. Depends on printer speed and colour. Standby power 30-60W
Energy content of petroleum fuels	Environmental Protection Agency USA, 2001	34.86 MJ/litre of gasoline; 38.66 MJ/L of diesel and 37.63 MJ/L of jet-fuel-kerosene
CO_2 emission coefficients for Japanese Railway, Ship and air transportation	Environmental reports-Toyota, 2001; Japan Railways East, 2002 and Japan Airlines (JAL), 2001	In grams CO_2 per ton-kilometre, Railways 21.7; Coastal services 35.6; Air 806 (available ton-km) or 110 g per passenger-kilometre
Carbon (or CO_2) content of petroleum fuels	Environmental Protection Agency USA, 2001	Diesel 69.34 g-CO_2/MJ and Jet fuel kerosene 67.18 g-CO_2/MJ computed from imperial units
Fuel consumption coefficients for different transportation modes	Environmental Reports-Japanese car makers (2002) and JAL (2001)	Airplane (1.76-2.71) x 10^{-2} kg fuel/seat-km or 0.327 litres per ton-km. Coefficients for trucks and cars from Japanese Automotive makers' reports.
Standard unit weight per air plane seat	Japanese airlines annual environmental report, 2001	65.8 kg per seat for Japanese domestic flights and 72.5 for International flights to and from Japan
Annual Japanese household energy consumption for climatic control	Williams et al, 2002	4 250 MJ/ household for climatic control only in Japan

The splitting of the report into smaller parts is done because most of the documents are too big for the average printer memory. The evaluated life cycle energy consumption of the annual report is 6.3 MJ if stored during the whole 3-year lifecycle of the server using the proportion of the hard disk space occupied by the Toyota report for 2002. If the report is stored for one year only, this comes down to 2.1 MJ. However in many cases, the reports are archived for some time and the energy share is more, depending on the number of years that it is stored on the server.

Also some companies like Nissan have an annual report occupying 1.8 MB only, roughly 12 % of the space occupied by the Toyota report. This would reduce the energy to store the report for one year to 0.25 MJ. The report is assumed to be stored for three years and viewed by an average of 30 000 stakeholders in that time. This is based on responses from the Japanese automotive industry. This renders the energy use per stakeholder too low, at 2.1 kJ. The other way is to convert the server production and supply chain cycles into a power measurement and consider how much of it is consumed during usage by the stakeholder. Assuming that the server is used for 24 hours a day, 365 days per year for three years, and the life cycle power is 88 W. When it is assumed that the annual report website is used by a stakeholder for 2 hours, the energy consumption related is 0.63 MJ.

5.2 Energy consumption in the use phase of the server ESU

The energy used by a small server has been estimated at 814 kWh (2930.4 MJ) per year (Brueniger, 2002). In this case, the server is taken as a very powerful PC of 120 W, much higher than this value. Its energy consumption during its 3-year life cycle is 11 353 MJ if it is fully on all the time. However, assuming that the report is stored for one year, occupying 30.4 MB of the 40 GB-server, the share of the annual report of the energy consumption is 2.88 MJ.

It is noted that this energy use makes the report to be available to all users for one year. The actual energy use per user will depend on the number of web browsers that read the web pages where it is stored. For example, the Toyota report for 2001 had 57 000 accesses, implying that the energy consumption was 51 joules per user. This is negligible. If one user uses the page as a sole user for 2 hours, the time estimated for reading the report through energy consumption would be 0.86 MJ. This assumes that the server contains the annual environmental report only, and that no other stakeholder is accessing it at that time.

5.3 Energy for computer use at home EHCU

It is assumed that the majority of the computers at home are the old models that have not benefited from B2B and B2C integration, hence with a production and supply chain life cycle consumption of 6 000 MJ (Cohen, 2001). Assuming that the computer at home is used 2 hours per day for 365 days a year for 5 years the life cycle power consumption of the computer using this data is 457 W based on a PC that has a life cycle energy consumption of 6 000 MJ for the production and supply cycles. In addition, the operational phase of the computer has to be calculated based on the power consumption during use.

The Environmental Protection Agency of the US estimates the energy requirements of a typical personal computer (PC) used 24 hours a day as 600 kWh (2160 MJ) per year. This assumes that the power output averages 68.5 Watts. This energy consumption can be reduced by about 40% when the power management features of the PC are enabled. The laptop power consumption can be as low as 10W, though the capacity would be also lower. The power consumption of a typical 14-inch (35 centimetre) monitor is 135 kWh (486 MJ) per year, when operating for 9 hours a day. This assumes a power rating of 40 Watts. This can come down to about 6 Watts for an Active matrix Mono Liquid Crystal Display (LCD) monitor. A conventional computer on average consumes 120 W. In general desktop computers are rated at 80-150 Watts. (EV Solar) There have been estimates, which also rate computers at 65.5 W, averaging out desktop and laptop models (Williams et al, 2002).

Sensitivity analysis can be considered for a powerful PC rated at 150 W as well. However, an average power rating of the PC is taken as 100 W, averaging out for laptop and desktop models, considering the fact that the computers are getting more powerful. The monitors were found to have a maximum power consumption of 120 W. This power rating is coming down due to technology improvements, particularly the use of LCD monitors. The average power consumption of the displays was taken to be 80 W averaging out for laptops and desktops and between the different types of displays found in homes. This means that an average computer and monitor combination power rating is taken as 180 W. Assuming that the computer at home is used 2 hours per day for 365 days a year for 5 years, the energy consumption of the use phase of the computer is 2365.2 MJ. The assumption is that the computer at home is used to access the environmental report web pages through the Internet. During this time the purpose of being in the room is to access and read this report only. Lighting of the room takes 100 W if incandescent lighting is used, 25 W if fluorescent tubes are used and 50 W if halogen lamps are used.

A worst-case scenario is assumed and 100 W is taken as the power for lighting. Annual household energy consumption for climatic control is taken as 14.250 MJ (Williams et al, 2002). 900 W per household is the power consumption, assuming that usage is for 365 days, for 12 hours a day. Assume an average of 3 rooms per household power consumption per room is 300 W. Combining the production and delivery life cycle power of the PC, power to operate the computer, the power for lighting and the power used for air conditioning, the power requirement for using the Internet from home is 1 040 W. Assuming that the user reads the report online for a total of 2 hours, the total energy consumed at home is 7.49 MJ. The energy consumed at home reading a paper-based report with the computer off is 2.88 MJ.

5.4 Energy use at the motor company server room ESS

Energy is consumed at the place where the server is stored at the car company and at home when the stakeholder is using the Internet or reading the annual environmental management report. The use of lighting, heating and cooling is required at these places. Assuming that the server occupies a square meter and that the energy is 1804 MJ/m^2 per year, (JAL, 2001) storage energy use for the server during the 2 hours of use is 0.41 MJ.

5.5 Energy use by networking and telecommunications equipment EN

Energy used by the networking and telecommunications equipment is very difficult to estimate due to lack of data. These include the public telephone network analogue or digital, internet protocol network, port of presence network, firewall, secure socket layer accelerator, cell site equipment, and transmission cables like fibre optic, private branch exchanges, local area network switches, load balancers, routers, hubs, wide area network switches, remote access servers and cable model termination systems to facilitate the use of Internet. (Matthews, 2002: Miyamoto, 2001: Roth, 2002) .Estimates have put the energy consumption per telephone line at 90-144 kWh/year per line. (Herring, 2001) This includes space heating at the exchanges, running the exchange equipment, operating air conditioning and ventilation systems and power used by the telephone line.

The levels of energy consumption when taken at a national level are high. For example, Computer networks and telecommunication networks consumed 6.2 TWh and 6.4 TWh respectively in year 2000 (Roth, 2002). The energy consumption of the networking and telecommunications equipment is taken as 288 kWh at most, assuming that computer networks consume the same amount of energy as the telecommunication network. Under these assumptions, the energy consumed browsing the Internet for 2 hours is 0.24 MJ. The end of life of the computer equipment and network were ignored because of the fact that the share of the annual report to other web surfing activities and ICT used is an extremely small fraction.

The data sets for the electronic systems are shown in Table 3.

Table 3: Data sets used for inventory analysis of the traditional system

Process or aspect	*Data source*	*Values and comments*
Serve production and supply life cycle energy	Williams et al 2002, Cohen 2001 and Herring 2001	Assumed value of 8300 MJ/ server based the mentioned data sources.
Life span of a server	Computer makers' information	3 years for ubiquitous use
Server energy consumption	Estimation, Makers' information	120 W, using large PC
File size of average company annual environmental report	Electronic annual reports for Japanese carmakers on Internet	30 MB since information is stored in at least two formats
Personal Computer (PC) production and supply life cycle energy	Cohen, 2001; Herring, 2001; Williamset al, 2002	Assumption of 6000 MJ/PC based on these data sources
PC and monitor power consumption during it use	Environmental Protection Agency website, EV Solar, Williams et al, 2002	180 Watts combined consumption based on average of 100W for PC and 80W for Monitor
PC life span	Estimation, Makers' information	5 years for intermittent use
Lighting power at home	Estimation, Williams et al, 2002	100 W per room
Internet browsing time to read annual environmental report	Own experimental analysis reading reports on Internet	2 hours. Period varies on the purpose of reading. More time for researcher
Climatic control power per room	Williams et al, 2002. Estimation	300 W per room
Lighting, heating and cooling server at Automotive Company premises	Japan Airlines Annual Environmental Report 2001	1804 MJ/m^2 for Japanese companies
Computer and telecommunication energy for environmental reporting	Herring, 2001 and Roth, 2002	288 MWh/telephone line based on United Kingdom and USA data.

6. Results and discussion

The results for the six scenarios are given in Figure 7 for the cases when the company uses its own transport to a non-collect and delivery post office and when the collect and delivery post office collects the mail. These are followed by classification of the results for own delivery for the different trip legs in Figure 8. In figure 8 there are only three trip legs for scenario 1 and four trip legs for scenario 2. The rest of the scenarios have six legs.

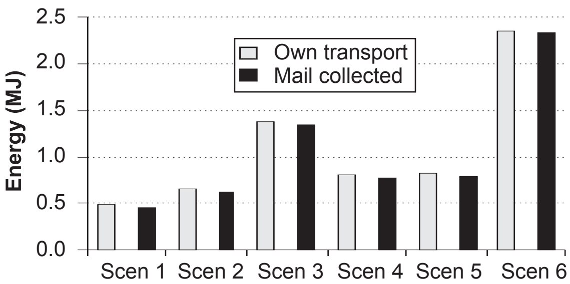

Figure 7: Energy use for posted annual environmental report for the six scenarios

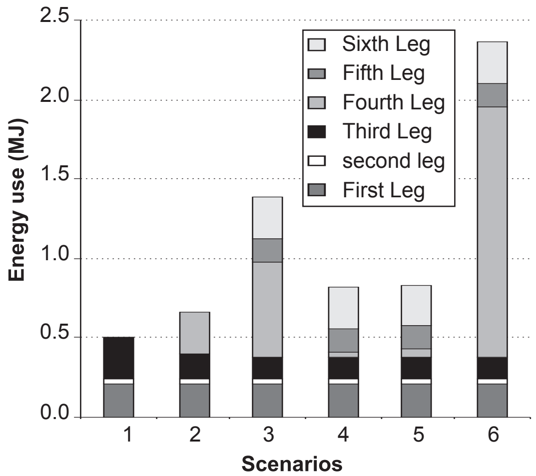

Figure 8: Classification of the results by trip legs for own transport energy use

The results for the transportation of the environmental report and assumptions used are in Table 4. It is clear that there is very little difference in energy consumption under the stated assumptions, between the company taking the environmental report to the post office and the post office vehicle collecting it. The critical parameter is the total mass transported by the vehicle. If the report was the only item transported, energy consumption per environmental report would shoot up to 9 MJ. The energy use could be reduced by the use of ultra-low fuel consumption vehicles, like hybrid cars. For all scenarios, the weight factor continues to be a dominant parameter.

The energy difference between scenarios 1 and 2 is less than 0.15 MJ. The use of the railway and coastal shipping is most energy efficient for the postal system. However, competition from other information delivery services makes it to use road and air transport, even though they are the most energy inefficient. The full results for all the scenarios are shown in Figure 9. It is clear that electronic dissemination of the environmental report uses less energy for delivery to stakeholders at any place in Japan for the stated assumptions.

Table 5 shows the total energy involved in paper-based annual environmental report dissemination, when recycled paper is used and the delivery process involves the use of an airplane in transporting the mail. This was found to be the normal distribution channel for letters going to regions that are far away in Japan. The results indicate that for the paper-based reports, most of the consumption is attributable to paper production, followed by energy spent in a room where the reader is and annual environmental report transportation. The use of virgin wood in paper production increased the total energy consumed per report to 20 MJ, more than double the energy used for the electronic version. For the electronic delivery of the report shown in

Table 4: The results of the six different scenarios for mail transportation

Scenario	1st Leg	2nd Leg	3rd Leg	4th Leg	5th Leg	6th Leg	Total
Scenario 1	0.20	0.03	0.26	-	-	-	0.49
Scenario 1a	0.17	0.26	-	-	-	-	0.43
Scenario 2	0.20	0.03	0.15	0.26	-	-	0.64
Scenario 2a	0.17	0.15	0.26	-	-	-	0.58
Scenario 3	0.20	0.03	0.15	0.59	0.15	0.26	1.38
Scenario 3a	0.17	0.15	0.59	0.15	0.26	-	1.32
Scenario 4	0.20	0.03	0.15	0.03	0.15	0.26	0.82
Scenario 4a	0.17	0.15	0.03	0.15	0.26	-	0.76
Scenario 5	0.20	0.03	0.15	0.05	0.15	0.26	0.84
Scenario 5a	0.17	0.15	0.05	0.15	0.26	-	0.78
Scenario 6	0.20	0.03	0.15	1.57	0.15	0.26	2.36
Scenario 6a	0.17	0.15	1.57	0.15	0.26	-	2.30

Table 6, the use of energy at home is a dominant parameter. The other sources of energy use are comparatively less significant.

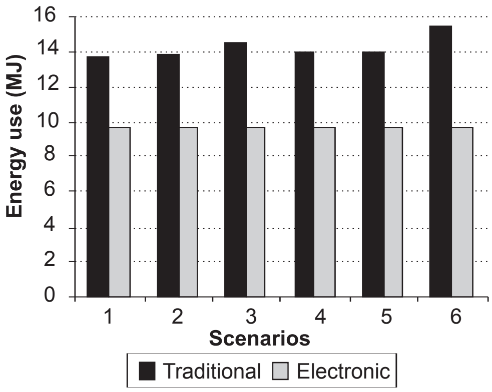

Figure 9: Comparison of traditional and electronic delivery of the report for all scenarios

Table 5: Energy consumption recycled paper-based report

Energy report recycled paper MJ	8.92
Printing energy/report MJ	0.18
Energy trans. Printer to company MJ	0.03
Storage energy MJ	1.10
Energy- Postal Transport MJ	2.36
Room energy- reading report 2hrs. MJ	2.88
Energy Trans. Recycle centre MJ	0.05
Total traditional energy MJ	15.52

Table 6: Energy consumption internet report

Cycle energy server – 2 hrs MJ	0.63
Server energy sole user MJ	0.86
Home + PC energy for 2 hrs MJ	7.46
Network energy-2 hours MJ	0.25
Total energy use MJ	9.20

6.1 Sensitivity analysis

The difference in energy consumption is very significant, but can be easily reversed if the reports are printed at home. The total energy per electronic report that is printed, in addition to the normal 2-hour browsing through the Internet, would increase to 18.34 MJ when recycled paper is used and 22.80 MJ when new wood pulp paper is used in this case, well above the traditional method (15.51 MJ) of information distribution. When the mass of the annual environmental report was reduced, it displayed high sensitivity between 100 and 130 grams. The electronic system was found to use more energy for all scenarios, except scenario 6, when an airline was used to transport mail for a 110 gram-report.

The results are displayed in Figure 10. This suggests that the posting of summarized annual reports of less than 25 pages have advantages over electronic versions. The model was also very sensitive to the time spent reading the report, which was also regarded as being equal to the Internet browsing time. High sensitivity was displayed between 3 and 4 hours.

Figure 11 shows the results for a reading/browsing time of 4 hours. The traditional system has clear advantages over the electronic system for all scenarios. If stakeholders need to study the reports in detail, involving more reading time there may be advantages in printing the reports.

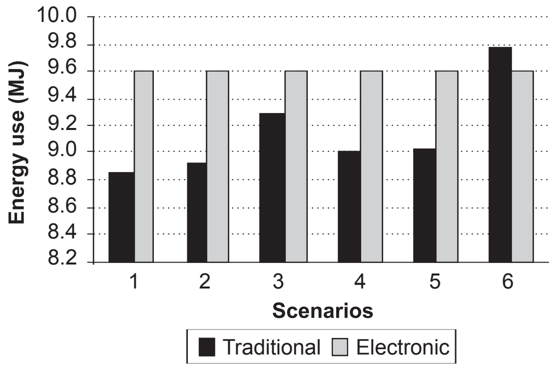

Figure 10: Comparison for the two systems when the report weight is 110 grams

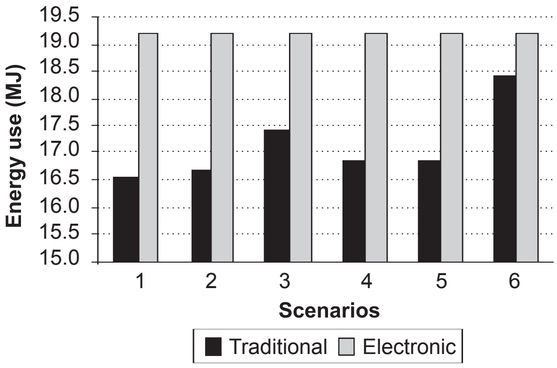

Figure 11: Comparison of the two systems when reading/browsing time is 4 hours

In total 41 variables used in the model were tested for sensitivity. The results are shown in Table 7. The electronic system was noted to use more energy when the personal computer used at home had a life span, which is below one and half years and when the server was dedicated to environmental reporting only and consumed 1000 W. These are very unlikely scenarios. The rest of the variables did not change the main facts of the results when subjected to plausible variation. They just changed the magnitude of the energy used, without affecting the comparative positions, thus not affecting the conclusions of the study. The model is therefore considered to be adequate for the purposes of the study.

Table 7: Sensitivity analysis of all the variables

Variable factor considered	*Base value*	*Plausible variation*	*Variation effect on electronic energy use in MJ (% change)*	*Variation effect on traditional energy use*
Distance from company to nearest post office (km)	2.2	+500% -50%	16.33 (+5%) 15.42 (-0.6%)	No effect. Less energy for electronic system
Fuel efficiency of company car used to deliver mail (km/L)	10	+250% -40%	15.38 (-0.9%) 15.66 (+0.9%)	No effect. Less energy for electronic system
Mass the Annual Environmental Management Report (kg)	0.223	+60% -60%	22.43 (+44.6%) 8.62 (-44.6%)	Traditional can be better than electronic
Total net mass carried in the company vehicle used (kg)	10	+5000% -97.5%	15.33 (-1.2%) 23.39 (+50.7%)	No effect. Less energy for electronic system
Postal Service vehicle distance covered to collect mail (km)	10	+100% -90%	15.66 (+0.9%) 15.35 (-1.16%)	No effect. Less energy for electronic system
Postal Service vehicle fuel efficiency <1000cc (km/L)	18	+100% -60%	15.40 (-0.8%) 15.82 (+1.9%)	No effect. Less energy for electronic system
Total net mass carried by Postal Service Vehicle (kg)	30	+1600% -95%	15.33 (-1.2%) 18.72 (+20.6%)	No effect. Less energy for electronic system
Non-collect/delivery-Collect and delivery Post Office dist. (km)	5	+300% -80%	15.62 (+0.6%) 15.50 (-0.1%)	No effect. Less energy for electronic system
Fuel efficiency of car used between the post offices (km/L)	8	+50% -25%	15.51 (-0.05%) 15.54 (+0.05%)	No effect. Less energy for electronic system
Total net mass carried by the vehicle (kg)	200	+400% -90%	15.50 (-0.1%) 15.81 (+1.9%)	No effect. Less energy for electronic system
Postal Service motorcycle round trip delivery distance/mail (km)	20	+100% -75%	15.79 (+1.7%) 15.33 (-1.2%)	No effect. Less energy for electronic system
Motorcycle fuel efficiency for nail delivery (km/L)	35	+20% -80%	15.48 (-0.2%) 16.57 (+6.7%)	No effect. Less energy for electronic system
Total net mass carried by motor during delivery (kg)	20	+50% -98%	15.44 (-0.4%) 28.37 (+82.8%)	No effect. Less energy for cyc electronic system
Collect/delivery-Collect/delivery distance in same region (km)	50	+100% -90%	15.84 (+2.06%) 15.23 (-1.9%)	No effect. Less energy for electronic system
Fuel efficiency of vehicle used between the post offices (km/L)	8	+50% -25%	15.42 (-0.6%) 15.63 (+0.6%)	No effect. Less energy for electronic system
Total net mass carried inter-collect/delivery post offices (kg)	400	+150% -90%	15.33 (-1.2%) 18.38 (+18.4%)	No effect. Less energy for electronic system
Collect and delivery to regional post office distance (km)	50	+500% -90%	16.97 (+9.4%) 15.25 (-1.7%)	No effect. Less energy for electronic system
Fuel efficiency of 6-ton truck used to carry mail (km/L)	3.5	+20% -20%	15.46 (-0.3%) 15.60 (+0.6%)	No effect. Less energy for electronic system
Total net mass carried by the 6-ton truck-bulky mail (kg)	1000	+500% -20%	15.27 (-0.9%) 15.59 (+0.5%)	No effect. Less energy for electronic system
Distance between regional post offices (km)	350	+500% -90%	23.38 (+50.7%) 14.10 (-9%)	No effect. Less energy for electronic system
Fuel efficiency of 10-ton truck used to carry the mail (km/L)	3	+20% -20%	No change No change	No effect. Less energy for electronic system
Total net mass carried by the 10-ton truck-bulk mail	2000	+400% -50%	No change No change	No effect. Less energy for electronic system
Fuel/Energy efficiency- Railway cargo in Japan (MJ/ton-km)	0.31	+10% -10%	No change No change	No effect. Less energy for electronic system
Fuel/Energy efficiency – Japanese coastal shipping (MJ/ton-km)	0.51	+10% -10%	No change No change	No effect. Less energy for electronic system
Fuel/Energy efficiency of Airline cargo on Japan (L/ton-km)	0.47	+20% -20%	15.83 (+2%) 15.20 (-2%)electronic system	No effect. Less energy for
Production life cycle energy use of virgin wood paper (MJ)	60	+10% -30%	21.31 (+6.7% virgin paper) 15.96 (-20% virgin paper)	No effect. Less energy for electronic system

Table 7 (continued): Sensitivity analysis of all the variables

Variable factor considered	*Base value*	*Plausible variation*	*Variation effect on electronic energy use in MJ (% change)*	*Variation effect on traditional energy use*
Production life cycle energy use of recycled paper (MJ)	40	+10% -25%	16.41 (+12.3%) rec. paper 13.28 (-14.4%) rec. paper	No effect. Less energy for electronic system
Energy used by printer per page printed (KJ)	3	+300% -50%	16.05 (+3.5%) 15.42 (-0.6%)	No effect. Less energy for electronic system
Energy used for the storage of the report at company (MJ)	1.1	+100% -30%	16.61 (+7%) 15.18 (-2.1%)	No effect. Less energy for electronic system
Server production/delivery life cycle energy use (MJ)	8300	+25% -25%	No change. More energy for traditional system.	9.35 (+2.2%) 9.04 (-1.7%)
Life span of the server used by the company (years)	3	+100% -35%	No change. More energy for traditional system.	8.88 (-3.5%) 9.54 (+3.7%)
Server average power consumption (Watts)	120	+900% -25%	No change. Electronic system can use more energy.	16.97 (+84.5%) 8.98 (-2.4%)
Home personal computer (PC) life span (years)	5	+100% -60%	No change. More energy for traditional system.	7.55 (-17.9%) 14.13 (+53.6%)
Home PC production/delivery life cycle energy use (MJ)	6000	+25 -25%	No change. More energy for traditional system.	10.02 (+8.9%) 8.37 (-9.0%)
Home PC average daily usage time (hours)	2	+100% -50%	No change. More energy for traditional system.	7.55 (-17.9%) 12.48 (+35.7%)
Home PC average power consumption (Watts)	100	+100% -50%	No change. More energy for traditional system.	9.92 (+7.8%) 8.84 (-3.9%)
Home PC Screen/Display power consumption (Watts)	80	+25% -95%	No change. More energy for traditional system.	9.34 (+1.5%) 8.65 (-6.0%)
Telecommunication/computer network energy use/year (MJ)	1037	+100% -50%	No change. More energy for traditional system.	9.43 (+2.5%) 9.08 (-1.3%)
Browsing time for electronic environmental report (hours)	2	+100% -80%	18.39 (+18.6%) = electronic 13.21 (-14.8%)	18.39 (+99.9%) 1.84 (-80.0%)
Room lighting power consumption (Watts)	100	+100% -75%	16.23 (+4.6%) 14.97 (-3.5%)	9.92 (+7.8%) 8.66 (-5.9%)
Room heating/cooling power consumption (Watts)	300	+20% -20%	15.95 (+2.8%) 15.08 (-2.8%)	9.63 (+4.7%) 8.76 (-4.8%)

6.2 General discussion

It is difficult to define and measure the errors due to the fact that life cycle energy analysis is a conceptual construct that cannot be directly measured. It is not possible to set up experiments to prove or disprove the values obtained. The models used rely on external data sources, whose quality is often very difficult to assess.

The available data is also full of gaps necessitating the use of assumptions based on plausibility arguments. The errors in analysis can be deconstructed into two main groups of issues. The first are to do with whether the definition of life cycle energy is appropriate or validation errors and the second are to do with whether the calculations accurately reflect the defined model, verification errors. The setting of the system boundaries, comparisons of goods and services and the choice of factors used in the model can be questionable.

The fact that people still enjoy reading paper-based information as opposed to electronic information on a screen is not considered. These are habits, which take a long time to change. There are also problems associated with the effect of screen glare on eyes due to prolonged used of computers. Constant keyboard, touch screen and mouse manipulation can be irritable for some users. The normal practice by people is to have information printed on paper, a tangible resource. It is difficult to assess the number of people that print out the reports at home. More work could be done in that area.

The second aspect of error relates to issues like data quality, the assumptions based on plausibility arguments and the averaging out of data. Attempts to take care of this aspect have been through sensitivity analysis, which has been done for the feasible variables. The range over which the results hold have been examined and the behaviour of the system fully analyzed. For example, while it is expected that the report storage energy estimate has been overstated, since commercial book storage energy is higher than company report storage energy, sensitivity analysis shows that its impact is negligible. The model ignored the contribution of the life cycle production and delivery energy of the printer and the ink used to print the reports.

However, the fact that the electronic system is found to be more favourable despite this indicates that the related benefits could be more than estimated in the study. The sensitivity analysis of the printer energy per page was tested over a very wide range from +300% to -50% and found to have little effect on the total energy consumed. The fact that the printer and ink life cycle energy was not considered does not affect the result much due to the fact that the number of pages printed per report is very few. However, errors may arise, when comparing results for many copies of the report, but these would be very low. The study could have also covered partial electronic distribution of the annual environmental reports using compact discs (CDs) or other electronic storage devices that can store information. This would involve the posting of the storage devices through the postal system or through fast-delivery service companies. This was not taken into account in this case, since the Japanese automotive industry does not use this system. However, separate studies can be done to consider the feasibility of such a system as a third alternative distribution method.

Hischier et al, 2002 compared the use of a CD-ROM for replacing printed conference proceedings and found out that the if the CR ROM owner printed 20-30% of the contents, the environmental cost was the same as when the full content was printed in book form. This suggests that the energy benefits of using CD-ROMs might be less than that of a complete electronic system.

Toyota Motor Corporation for which data was available distributed 29 000 environmental reports. The associated energy use is estimated at 450.000 MJ. This figure could easily increase to four times this amount (1.800 gigajoules (GJ)) if the current number of Internet hits signifies the demand that would need to be supplied with the reports. This would appear to be an insignificant 0.0004% of the lifecycle energy of all the 5 404 216 cars (Toyota 2002 annual environmental report) produced by the company in the year 2002, estimating the life cycle energy of each car to be 83 GJ (Herring, 2001).

Toyota uses less energy since it is not involved in the full life cycle of the car production process. Toyota North America estimates that it uses 9.2 GJ per vehicle, being the average of site-wide energy use in all of Toyota manufacturing facilities in North America. The energy used for environmental reporting by the corporate company then jumps to about 0.0036%. Given that according to the 2002 environmental report, Toyota had 57 production companies and 17 companies in other fields certified to ISO 14001, each with its own environmental system reporting needs, with the percentage of energy used in environmental reporting is more. When compared against the energy used to maintain the environmental management systems, the percentage contribution of environmental reporting is expected to become very significant. The fact that as of January 2007, there were 21 779 Japanese companies certified to ISO 14001 (Tsujii, 2007) and reporting on their environmental performance, suggests that the energy consumption associated with environmental reporting in general can no longer be ignored.

The study has compared on a one to one basis the energy required to distribute the environmental report thorough the traditional and electronic system. However, when the distribution of information to 100 000 people is done, the electronic methods result in more energy savings, since the power consumption of the server and the network is fairly independent of the connected ports (Matthews, 2002). Many interested stakeholders can access the company server simultaneously and the life cycle energy of such equipment is shared by all of them, not by one user as was assumed in the model. The fact that the use of the PC at home accounts for more than 80% of the energy used by the electronic system however, limits the impact of these savings.

It is clear that 50% energy use reduction can occur if electronic systems replace traditional ones in environmental reporting. If the total ISO 14001 environmental management system is taken into account, more energy impacts will be identified. This is because the implementation of the system is both labour and paper-intensive. Energy is consumed through occupation of office space, paper use in documentation and recording, auditing, system review, training and education, system monitoring and control and by people running the system. These are areas, which need further detailed study. The results here are a part of the critical pieces that seek to resolve the issues regarding energy use in ISO 14001 environmental management systems. The shortening of annual environmental reports to 25 pages (110 g) as shown in the sensitivity analysis reverses the advantages of the electronic system. However, this could affect the quality and effectiveness of the disseminated information. The reduction should be done with care because it might be the case of 'cutting the baby in half'. Nevertheless, the use of tables and figures in the reports can reduce the text content of the reports. The fact that there is a chance to compromise the quality and integrity of the report further supports the viability of the strategy to use electronic dissemination.

This study has helped to define the performance and behaviour of online environmental management information transmission compared to sending paper copies of the report through the ordinary postal system. It has considered net-energy analysis using LCA, with particular attention to paper consumption and distribution systems and comparisons with alternative electronic systems in environmental management information systems.

A first attempt has been made to model energy use in the Japanese postal system and this model could be useful in a number of analyses. The same can be done for postal transportation systems in Southern Africa and parallel studies conducted. The study contributes to the debate on whether electronic annual environmental reports should be encouraged. It informs research and organizations analyzing the effects of ICT on the environment. It defines the variables that play a key role in determining the environmental efficiency associated and maps out crossover points in efficiency. The model can be used to forecast energy, transportation and material demands more easily, assisting to strategize production capacity and technological investments and informing response to climate change.

The study has looked at one small aspect of an EMS at a micro-level. However, the importance of such studies is that they form the key pieces of the overall complex problem of the environmental effects of ICT usage in various organizations, particularly when applied to an EMS. The study helped to identify critical areas where energy use can be reduced and ways to do so that can be applied in any company located in any country after some adaptation and changing of the assumptions. The general environmental impacts associated with distribution of the reports include energy use reduction, dematerialization, and transport reduction, transport substitution, replacement of a product with a service and reduction of production effort. However, the focus in this study has been on energy use only.

It was also found out that some of the electronic pages of the annual environmental management reports of the Japanese automotive companies were very difficult to view due to excessive use of graphics, colour and pictures. Such web pages take a long time to download onto a screen, resulting in more browsing time and energy use. It is suggested that organizations provide a second, easy to download and view report summary, which is less than ten pages. If the browser prints such a report, the environmental impacts associated will be less due to minimal energy use. The use of more environmentally friendly transport vehicles by the post office reduces CO_2 emissions.

Japan Postal Services has introduced low emission vehicles in line with the Japanese Law concerning the Promotion of Procurement of Eco-friendly Goods and Services by the State and Other Entities, also know as the Law on Green Purchasing. The organization had 94 electric vehicles, 3 natural gas fuelled vehicles and 159 hybrid vehicles by the end of 2001. Expanding the use of such vehicles in letter and parcel delivery will have a positive environmental impact.

7. Conclusions

The main conclusions from this study are as follows:

- The postal transportation system generally uses comparatively less energy that the paper production life cycle and room energy used when reading a report. This is most pronounced for all other scenarios except when a truck or airplane is used, in which case the energy use is more significant. Sensitivity analysis has also shown very little benefits in focusing on this area when trying to reduce energy use and environmental impacts.
- The general findings show that for the stated assumptions, electronic is better than traditional transmission of annual environmental reports. This indicates that the current move towards the electronic report is the right thing to do.
- Home energy use increases significantly when the electronic system is used, 7.46 MJ compared to 2.88 MJ in the case of the traditional system.
- Printing the reports at home using recycled paper does not seem to affect the benefits of the electronic system. However, use of virgin wood reverses the situation.
- The reduction of the report size and weight results in the traditional system indicating better energy performance. Reports of 10 – 25 pages are therefore recommended for traditional systems.
- The performance of the two systems is affected by the browsing and reading time of the report. It is concluded that if an interested party wants to study the report for 4 or more hours, it would be best for them to get a printed copy.

The issues discussed in this paper can be used to draw parallels and analogies with other communication issues in organizations. In the Japanese car industry for example, Toyota produces two books used for training its employees about environmental issues worldwide and the environmental management system within the organization. These are available online and this mode of information transfer can be compared with the printing of the books and issuing them to the employees. Updating them periodically poses similar challenges too. The use of in-company newsletters on environmental issues and daily, weekly, monthly or quarterly updates can also draw parallels from this study. General usage of ICT in other EMS areas like electronic auditing and use beyond the EMS in a company can also be considered, like general paper use and replacement, company-wide transport reduction and substitution and general environmental impacts of e-commerce. Some of the generalizations of this study can be extended to these proposed system models.

This paper has concentrated on transportation energy and dematerialization in the annual environmental management reporting as part of ISO 14001 EMS communication. There is need for additional work to deepen and broaden understanding of the factors identified. The actual distances to the customers that request the environmental reports can be determined using postal codes and comparisons of environmental impacts of the two systems can be more accurately determined. Yet this helps the accuracy of the evaluation of historical performance, and it does not help to predict the nature of these variables in future. The sensitivity analysis done is more useful for this. The model used is therefore considered adequate for the purposes of the study. The lessons and results of this study are useful globally and can inform research, studies and energy conservation decision making in environmental reporting in Southern African countries. Future work could target and adapt the study to environmental reporting in South Africa in particular.

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