LIFE CYCLE ASSESSMENT OF PAPER TOWEL AND ELECTRIC DRYER AS HAND DRYING METHOD IN THE UNIVERSITY OF MELBOURNE

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Abstract

Nowadays products, services, or technologies are proactively evaluated toward environmental performance by using the life cycle assessment (LCA). The assessment cover the whole life cycle from cradle to grave hence the product performance can be analyzed or compared with others for product development or for making a decision. The University of Melbourne currently installed towel dispenser by means of hand drying method in the entire campus. As some has suggested that electric dryer will provide more sustainable service than paper towel, a LCA study will be a good approach for comparing both methods. The study utilizes SimaPro software to generated database for impact assessment. The assessment method used in this study is Eco-Indicator 99. From the LCA study, electric hand dryer performed better in most of indicators. Electric hand dryer is therefore recommended to be used in the entire campus of the University of Melbourne.

Keywords: life cycle assessment, paper towel, electric dryer, SimaPro, Eco-Indicator 99

Introduction

There are some methods of hand drying including paper towel, cloth towel, electric hand dryer, and spontaneous evaporation. Two of these methods, paper towel and electric hand dryer, are commonly used in buildings such as office, commercial, and institution. Some people argue that paper towel can dry hands more efficient, quicker and also can function as cleaner media than hot air dryer (Blackmore, 1987; Knights, Evans, Barrass, & McHardy, 1993). Suspension of bacteria persists on wet hands but not on well-dried ones (Coates, Hutchinson, & Bolton, 1987) while hot air dryer can spread pathogenic bacteria onto hands and body, as well as inhaled and distributed across the room (Redway, Knights, Bozoky, Theobald, & Hardcastle, 1994). Others, on the other hand, claim that hot air dyer has less environmental impacts due to less emission and resource depletion (ERM, 2001) and having no significant difference on spreading bacteria compared to paper towel (Matthews & Newsom, 1987; Meers & Leong, 1989; Redway et al., 1994). Therefore a life cycle assessment of hand drying methods is necessary to reveal performance of both methods towards environment.

Life cycle assessment (LCA) is a study of a product's environmental impacts throughout its life cycle; from the extraction of raw material, production process, use, until its disposal into landfill (Hendrickson et al., 2006; PRE, 2006a). The LCA study comprises four stages, goal and scope, inventory, impact assessment, and interpretation.

Goal and Scope of The Life Cycle Assessment (LCA)

Goal and scope

The LCA study aims to compare the environmental performance of two methods of hand drying in the University of Melbourne, Parkville campus. The methods include:

1. Paper towel. Recently, the university installed paper towel dispenser in most toilets in the entire campus.
2. The proposed system is using electric hand dryer. Some people suggested that electric dryer is a better method of removing water than paper towel.

The functional unit is number of dries. It is assumed a 130,000 of dries for both methods.

System boundaries

This study will assess life cycle of hand drying methods of paper towel and electric hand dryer. Production process of both methods are assumed and simulated in SimaPro software. The systems of the two methods are illustrated in Figure 1 and 2. The system boundaries include raw material and disposal scenario which are larger than the point of use, the university. It is important to include those scenarios since point of use assessment will insufficient to reveal the real impacts of products or services. As can be seen from the flow diagram of both products, point of use comprise the smallest part of the life cycle. Thus involving all processes from cradle to grave to evaluate products sustainability towards environment are necessary.

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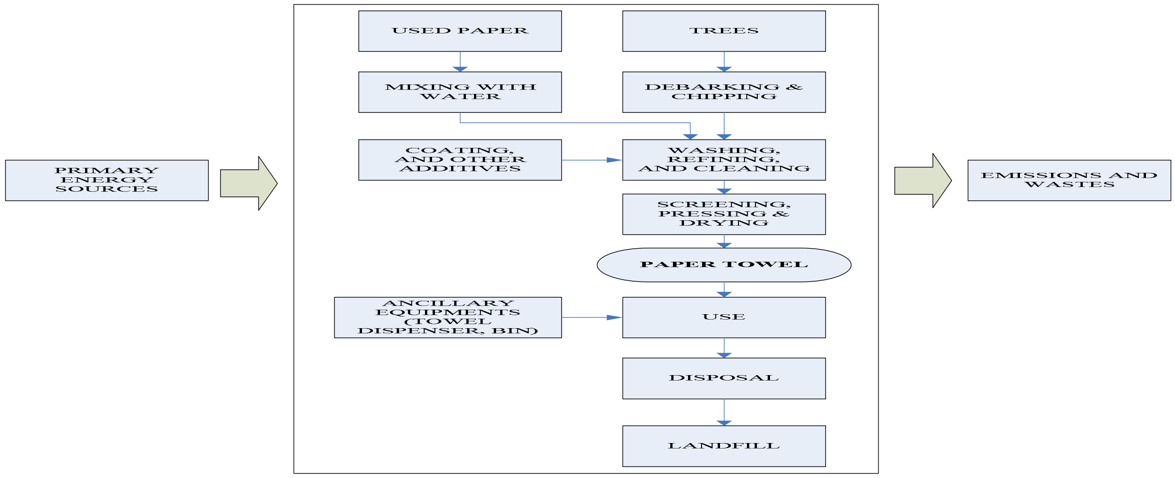

Figure 1 System boundary of paper towel

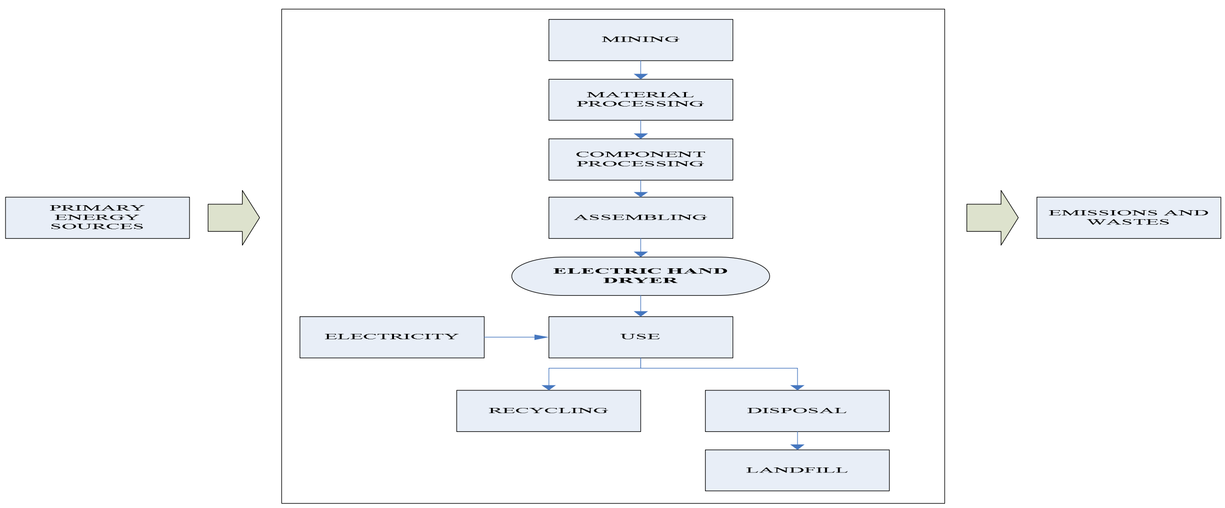

Figure 2 System boundary of electric hand dryer

Description of system

Paper Towel

A system of paper towel for hand drying method comprises paper towel, towel dispenser, and rubbish bin. It is assumed that a folded-paper towel has an average weight of 3.9 gram (ERM, 2001). Dispenser and bin are included in the SimaPro model as additional life cycle to paper towel LCA. The amount of paper required are 260,000 sheets with assumptions of 2 sheets of paper per use amounting to 1,040 kg of paper towel. The system is capable to provide 70 drying each day for the same lifetime with electric hand dryer.

Electric Hand Dryer

Electric hand dryer is assumed to have 5 years of lifetime which will require 1,083 kWh or 3.9 GJ for 30 seconds of average use. The electricity is supplied from coal-fired power plant through national grid and renewable resources. The renewables comprise 10% of energy used in University of Melbourne.

Life Cycle Inventory (LCI)

Data required for this study is mainly from SimaPro database. Since the databases are referred to European countries, the study is aimed to get the closest approach to the case in Australia. The demo version of software has some limitations, thus some data are presumed from previous report and web sources. Assumptions used in the data generation are contained in table 1. The assessment is based on some approaches. For paper towel, recycling paper is selected as the raw material which production mainly contributes to the life cycle of paper towel. In case of electric dryer, cast iron is chosen for raw material of casing.

Table 1 Assumptions made for LCA paper towel versus electric hand dryer

Description	Unit	Value
Number of drier		130,000
Electric Hand Dryer		
Lifetime	years	5
Time of drying	seconds	30
	hours	1,083
Electricity used	kWh	1,083
	GJ	3.9
Electricity from renewables	GJ	0.4
Electricity from coal	GJ	3.5
Physical properties		
Body: cast iron	kg	7
Components:		
a. Push button, wires: chromium	kg	0.1
b. Motor: copper	kg	1
Paper Towel		
Paper required	sheets/dry	2
Paper used	sheets	260,000
Paper weight	g	4
Total weight	kg	1,040
Drying capacity	dries/day	71
Ratio of paper recovery		1.0
Used paper required	kg	1,040

Source: calculation and some assumptions (AmericanDryer, 2006; ERM, 2001)

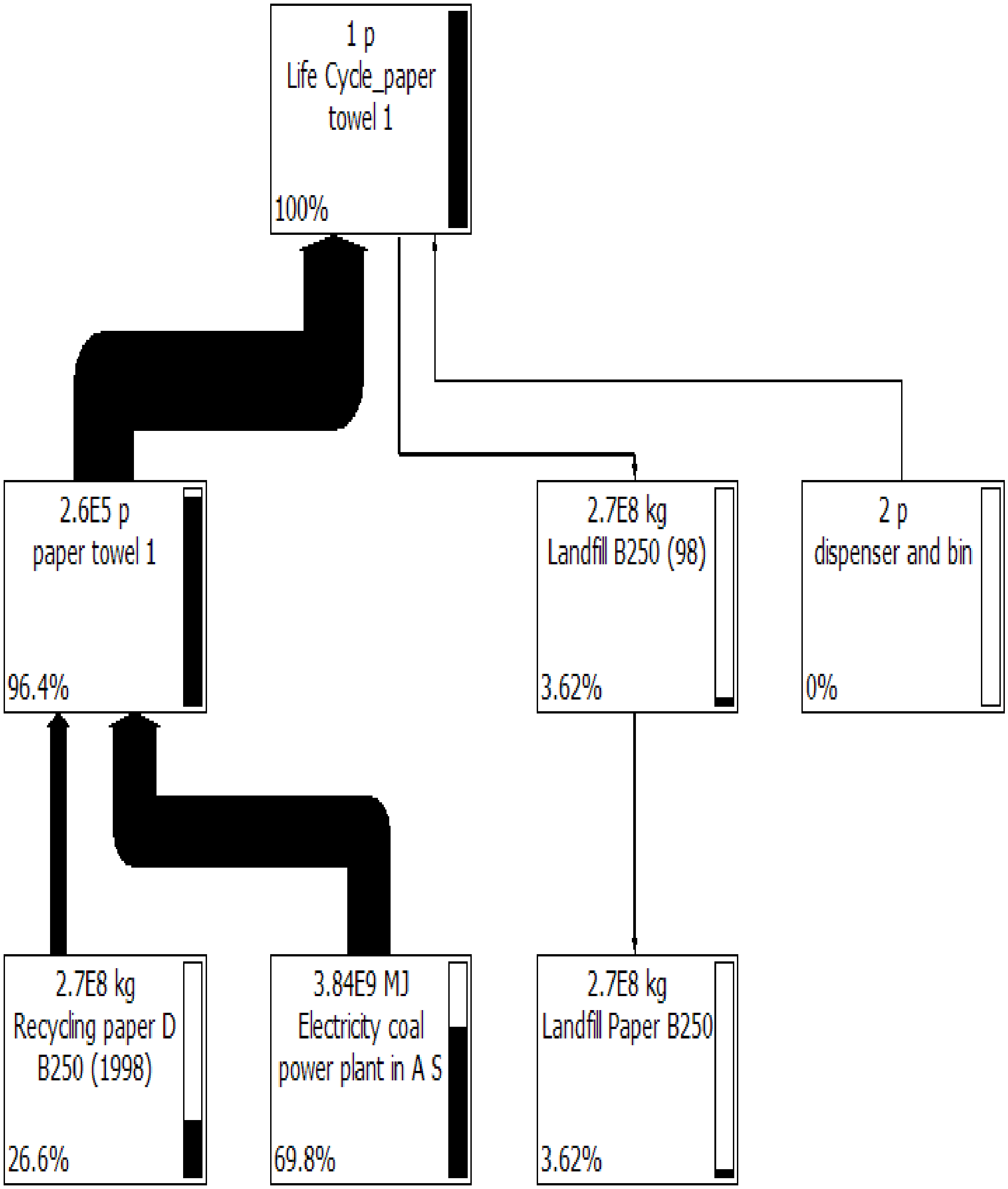

Figure 3 Flow diagram of paper towel life cycle

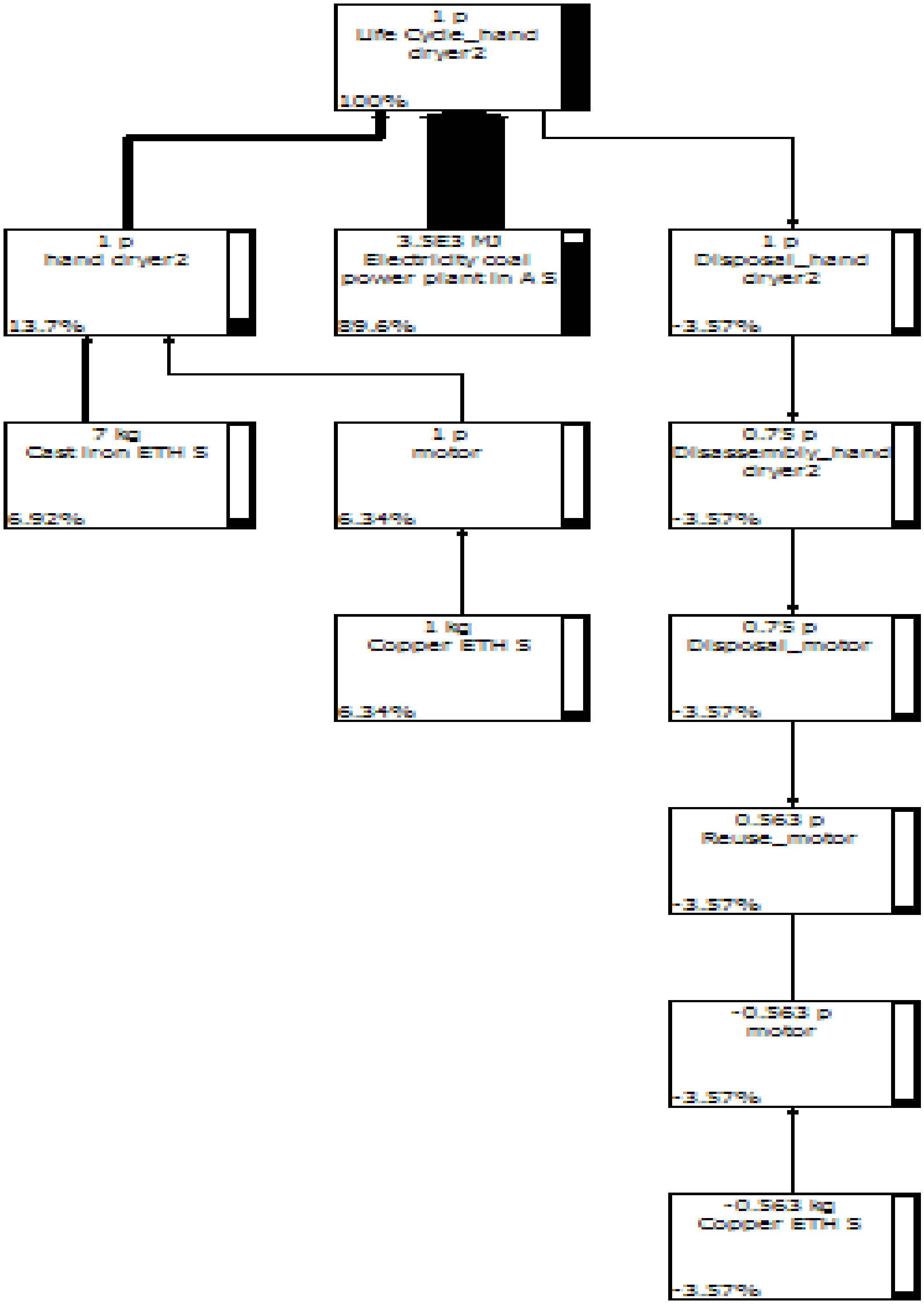

Figure 4 Flow diagram of electric hand dryer life cycle

Table 2 Inventory of life cycle of paper towel and electric dryer

No	Substance	Compartment	Unit	Life Cycle paper towel	Life Cycle hand dryer
1	Carbon dioxide	Air	kg	428.28680	973.90303
2	Heat, waste	Air	MJ	0.00000	6,470.74265
3	Methane	Air	kg	0.73365	3.55074
4	Nitrogen oxides	Air	kg	3.01137	0.93386
5	NMVOC, non-methane volatile organic compounds, unspecified origin	Air	kg	1.04046	0.13380
6	Particulates	Air	kg	0.81159	0.00008
7	Radioactive species, unspecified	Air	Bq	1,231,234,464.21077	3,481.37445
8	Sulfur oxides	Air	kg	3.86772	1.16828
9	Carbon	Soil	kg	1.56156	0.00243
10	Heat, waste	Soil	MJ	0.00000	1.21402
11	Nitrogen, total	Soil	kg	0.11864	0.00000
12	Chloride	Water	kg	22.29303	7.53015
13	BOD5, Biological Oxygen Demand	Water	kg	1.65287	0.00060
14	COD, Chemical Oxygen Demand	Water	kg	8.45854	0.00653
15	Heat, waste	Water	MJ	0.00000	835.80645
16	Lead	Water	kg	0.00069	0.00556
17	Nitrate	Water	kg	5.60461	0.02509
18	Phosphate	Water	kg	0.03814	0.06547
19	Radioactive species, unspecified	Water	Bq	11,388,397.66942	33.29128
20	Sulfate	Water	kg	11.74875	4.82549
21	Suspended substances, unspecified	Water	kg	4.24470	0.00016
22	TOC, Total Organic Carbon	Water	kg	5.28618	0.00000
23	Waste water/m3	Water	m3	47.04960	0.00000

Life Cycle Impact Assessment (LCIA)

Impact assessment of hand drying methods is using Eco-Indicator 99. It approaches the result at the end po-int or damage oriented approach which evaluates the damage caused by product onto three indicators, human health, ecosystem, and natural resource. The damage is weighted according to sustainability indicators (Dewulf & Langenhove, 2006; PRE, 2006b). Table 3 presents the impact burdens from using paper towel and electric dryer based on Eco-Indicator 99. There are 11 categories from three types of damage. Damage to human health is represented with Disability Adjusted Life Years (DALY) while damage to ecosystem quality is expressed with Potentially Disappeared Fraction (PDF). Mega Joule (MJ) surplus is expressing addi-tional energy required to extract low quality of mineral and fossil due to resources damage.

Table 3 Damage assessment of comparison of paper towel and electric dryer by using Eco-Indicator 99 method

Impact category	Unit	Life Cycle paper towel	Life Cycle hand dryer
Carcinogens	DALY	0.00003	0.00015
Resp. organics	DALY	0.00000	0.00000
Resp. inorganics	DALY	0.00058	0.00019
Climate change	DALY	0.00009	0.00022
Radiation	DALY	0.00000	0.00000
Ozone layer	DALY	0.00000	0.00000
Ecotoxicity	PDF*m2yr	7.79855	6.95432
Acidification/ Eutrophication	PDF*m2yr	23.01591	6.64641
Land use	PDF*m2yr	0.00000	6.45559
Minerals	MJ surplus	1.50593	17.87221
Fossil fuels	MJ surplus	704.41664	223.41701

Interpretation

Paper towel impact toward environment sus-tainability outperformed electric dryer by six to five of indicators. The sustainability indicators and the environmental impact of paper towel and electric dryer to environment are presented in below. The impacts assessment has limitation as they were generated from European da-tabases. This limitation is acknowledged to be a barrier for using SimaPro as methodological approach.

Environment impact

Environment effect is assessed based on damage to ecosystem quality which is represented in ecotoxicity, acidification/eutrophication, and land use categories. In land use which is claimed as the most potential impact category (Dewulf & Langenhove, 2006), electric dryer was outperformed by paper towel. Extraction of material for hand dryer assembly requires land clearing which directly threatens local and global ecosystems. Although land use plays significant role the ecotoxicity and acidification /eutrophication should be considered to increase environmental burdens. Paper towel method emits greenhouse gasses relatively higher than hand dryer (Table 5). Emission of sulfur oxides from the life cycle of paper towel is high and causing acid rain (acidification). Water pollu-tion from wastewater stre-am of paper towel life cycle is higher than hand dryer, especially on BOD, COD, TOC, sulfate, chloride, nitrate, and suspended solid contents (Table 2).

Table 4 Comparison of greenhouse gases emission from paper towel and electric dryer

No	Substance	Compartment	Unit	Life Cycle paper towel	Life Cycle hand dryer	GWP	GHG emissions (kg of CO2-eq)	
							Paper Towel	Hand dryer
1	Carbon dioxide	Air	kg	428.28680	973.90303	1	428.28680	973.90303
2	Methane	Air	kg	0.73365	3.55074	21	15.40667	74.56550
3	Nitrogen oxides	Air	kg	3.01137	0.93386	310	933.52610	289.49744
	Total						**1377.21957**	**1337.96597**

SOCIAL IMPACT

Human health indicator represents social impact of hand drying methods to user and community. Hand dr-yer surpassed paper towel in this indicator, particularly on significant effect from inorganic substances to respiratory (Dewulf & Langenhove, 2006). Paper towel made from recycling paper which process requires addi-tional substances to improve quality. Moreover, paper towel is not free from contamination of microorganism although it is stored in a dispenser. Used paper might contain bacteria and might spread disease through air circu-lation. In addition, paper towel method is labour intensive and is affected by users' behaviour. Cleaning rubbish bin could be unsafe for em-ployee when used and wet papers are scattered on the floor. On the other hand, utilizing hand dryer needs less maintenance and can provide complete dryness.

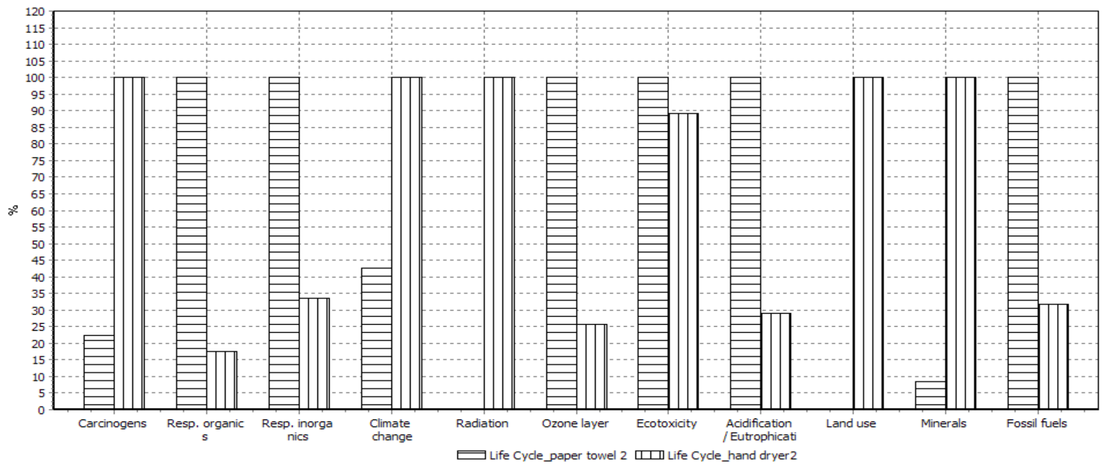

Figure 5 Using Eco-Indicator 99 to indicate sustainability indicator and to compare environmental sustainability of paper towel and electric dryer

Table 5 Single score of comparison of paper towel and electric dryer using Eco-Indicator 99

Impact category	Unit	Life Cycle paper towel	Life Cycle hand dryer
Total	Pt	37.61694	22.07429
Carcinogens	Pt	0.87837	3.94424
Resp. organics	Pt	0.03817	0.00670
Resp. inorganics	Pt	15.03315	5.03769
Climate change	Pt	2.45582	5.74911
Radiation	Pt	0.00000	0.02768
Ozone layer	Pt	0.00696	0.00179
Ecotoxicity	Pt	0.60829	0.54244
Acidification/ Eutrophication	Pt	1.79524	0.51842
Land use	Pt	0.00000	0.50354
Minerals	Pt	0.03584	0.42536
Fossil fuels	Pt	16.76512	5.31732

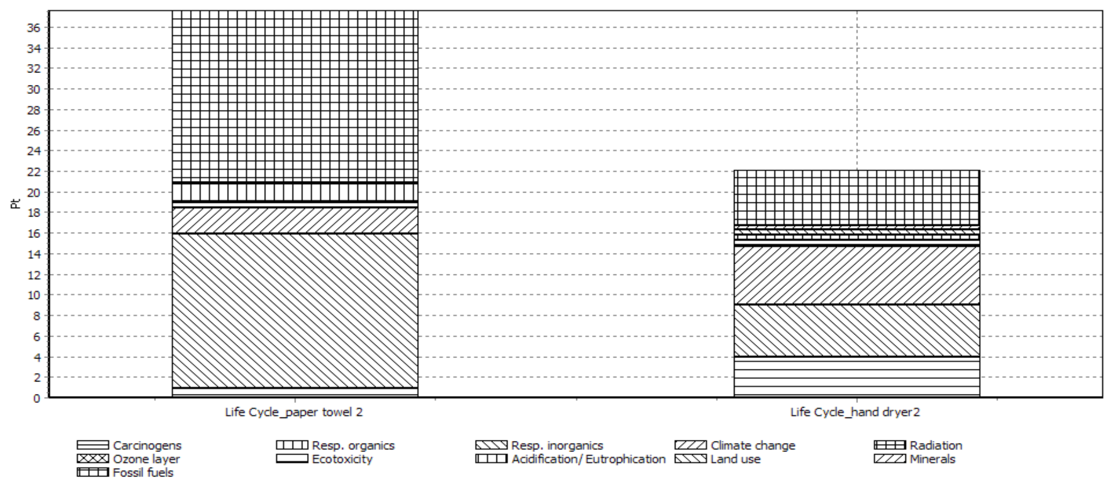

Figure 6 Using Eco-Indicator 99 to compare environmental sustainability performance of paper towel and electric dryer in a single score

Economic impact

Main economic impact from using paper towel is increasing effort on extracting fossil fuels. Paper towel method requires massive transport due to its bulkiness. Furthermore recycling process of paper follows the similar pattern as the new one, except less virgin material input. Therefore recycling paper uses higher energy for production.

The analysis from software was calculating economic impact throughout the life cycle hen-ce it did not distinguish the impact to the university. To approach more realistic result of economic burden from those methods, simple financial cost was calculated. Using paper towel will be costly than using electric dryer. Electricity for hand dryer throughout its life cycle costs for only A$ 152 compared to A$ 15,600 of paper towel cost. The comparison is using the similar functional unit used in the LCA study (Table 5 and 6). Cost of using hand dryer might be cheaper as the price of electricity in Australia is low vis-à-vis global prices (UIC, 2006). Moreover the high cost of using paper towel is attributed to the efficiency of drying. At least 2 sheets of paper are needed to drying hands and the price of a paper towel is expen-sive, 6 cent per sheet of paper towel compared to 14 cent per kWh of electricity for 120 of drying times.

Overall assessment is represent by single score where paper towel impacts toward all categories exceeded electric dryer. In total, impacts from utilizing paper towel are accounting for 37.6 point whilst electric dryer is only 22.1 point. In fossil fuels and respiratory effect from inorganic substances, electric dryer has much less impact than paper towel. Respiratory effect is con-sidered to be the most important category as human health is highly valued, while fossil fuel has major role in economic drive. A high on carbon dioxide emission from paper towel life cycle to the atmosphere is increasing potential of global warming that plays significant role in climate change. Thus paper towel has sig-nificant effect on both social as well as the environment

Table 6 Cost calculation of using paper towel compared to electric dryer in a given functional unit

Description	Unit	Value
Paper towel		
Price	cent/sheet	6
Paper required for 5 years	sheets	260,000
Financial cost	A$	15,600
Electricity for hand dryer		
Price	cent/kWh	14
Electricity used for 5 years	kWh	1,083
Financial cost	A$	152

Conclusion And Recommendation

In conclusion, electric hand dryer by means of hand drying method surpasses paper towel toward envir-onment sustainability performan-ces. The University of Melbourne is recommen-ded to consider utilization of electric dryer for replacing paper towel in the entire campus toilet. Improvement to reduce landuse should be targeted for optimum system. Landuse improve-ment can be addressed through best practice in mining. Implementing this approach will pre-vent environ-mental damage and social impact, better mineral exploration access, higher reli-ability of the outcomes, less risk and resistance from the key stakeholder, suppress financial cost in the closure and rehabilitation, and improved liability of post cloure (Envir-onment Australia, 2002). Therefore by reducing landuse damage, mineral, radiation, carcinogen, and climate change damages can be improved as well. The university may support the program by providing research assistance to the in-dustries.

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