

UBC Social, Ecological Economic Development Studies (SEEDS) Student Reports

**An Investigation into the Sustainable Attributes of Three Hand Drying Methods: Paper Towels,  
Cloth Towels, and Hand Dryer**

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**SUSTAINABILITY RECOMMENDATION REPORT**

**AN INVESTIGATION INTO THE SUSTAINABLE ATTRIBUTES**

**OF THREE HAND DRYING METHODS: PAPER TOWELS, CLOTH TOWELS,**

**AND HAND DRYER**

APSC 261

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## Abstract

As part of the Student Union Building (SUB) Renewal Project for the University of British Columbia (UBC), students were asked to conduct research sustainability implementations on various sections of the building. The following report will use the Triple Bottom Line criterion to analyze the use of cloth towel dispensers, electric hand dryers and recycled paper towels for hand drying in public washrooms of this new building. Environmentally, cloth dispensers and electric hand dryers consume very little energy. For cloth dispensers, one towel roll requires only 17 Watts per wash; and for a new generation hand dryer, 4.7 Watt-Hours per dry. Economically, both cloth dispensers and air dryers require material replacement approximately every five years. Cloth dispensers require regular cleaning of towel rolls, in contrast to air dryers where almost no maintenance is required. Recycled paper towels pose different issues as an alternative; they consume the most energy of the three methods proposed due to material, delivery and maintenance costs. However, studies have shown that of the three methods, paper towels are the most effective at removing bacteria from the hands. This is mostly due to the frictional removal upon wiping. However, cloth towels are not far behind in terms of removing bacteria and have a much smaller environmental impact. Looking in context, UBC is a public campus geared towards sustainability where students commute from various locations across the Greater Vancouver Area (GVA). The student population and diversity on campus prompt that one's health is of paramount importance while still upholding the idea of sustainability. Based on this criterion, this demonstrates that cloth towel dispensers are the best method of hand drying.

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## 1.0 Background and Motivation

This report is being written in order to provide a sustainability analysis of different hand drying methods for the newly proposed UBC Student Union Building (SUB). Currently, the new SUB project is in phase 6, the Design Development stage. In this stage the UBC Alma Mater Society (AMS) will be “developing a design that will meet the functional requirements and will result in an innovative building that projects an appropriate image and meets students’ sustainability goals.” (AMS, 2009). It is important that this design development process will be an “iterative process of back-and-forth between the architects and the student body to fine tune the design. Some difficult decisions and trade-offs will have to be made in order to meet the budget; it is important that these decisions be made by students in accordance with their stated principles for the New SUB Project.” (AMS, 2009).

As part of an APSC 261 project, the students were asked to pick a specific topic and perform a triple bottom line analysis of their topic. The projects included the following: sustainable laundry services, biodegradable/compostable utensils, sustainable paint, mattress disposal, compostable plastic bags assessment, light bulb sustainability, recycled paper towel versus electric hand dryers and sustainable computer hardware. From these projects our team picked the recyclable paper towels versus electric hand dryers. However, the team decided to add a third comparison to this project by instead of just looking at recyclable paper towels and electric hand dryers, our team will also be looking at cloth towel dispensers.

In order to provide an adequate comparison, our team will provide a triple bottom line analysis of recyclable paper towels, electric hand dryers and cloth towel dispensers. The triple bottom line analysis will consider the following: environmental impact, economic impact and social impact. The environmental impacts will look at the ecological footprint, the greenhouse gasses used and the embodied energy of each of the three technologies. The economic impact will look at the cost of the full life cycle of the technologies. This will include purchase price, maintenance, disposal and lifespan of each technology. Finally, the social impact will include ethical implications of the use of the three technologies as well as their effect on society.

In order to provide accurate information on the three different hand drying methods, research will be a key to this feasibility study. There are a variety of studies available online however, the information is sometimes biased as the research is usually performed either by companies in support of electric hand

drying or paper towels. Also, in terms of cloth towel dispensers, there is very little information available on this hand drying method. This is largely due to the fact that this method has been slowly phased out by companies but this does not mean it is less sustainable than the other hand drying methods. In order to accurately compare the three different methods calculations will be a fundamental aspect of this comparison report.

Through the analysis of the three different hand drying methods, this report will provide the AMS with valuable information on the feasibility of each hand drying method. This report will aim to put the interests of students first and foremost. Hopefully, this report will be considered in the final decisions made by the AMS in selecting the most sustainable hand drying method.

## 2.0 Cloth Towel Dispensers

### 2.1 Introduction

Cloth towel dispensers were a very common hand drying method used in the early 1990's. These hand dryers consist of a long roll cloth towel located inside the dispenser which loops back into the machine when the user would pull down on the cloth so that they can dry their hands on dry unused cloth. New cloth towel dispensers no longer require the user to pull down on the cloth; instead an infrared sensor used in conjunction with a motor provides a fresh section of the cloth roll to the user after every use. These new dispensers have improved the hygienic capability of this hand drying method as one no longer has to be concerned about touching a part of the cloth that someone else used. A picture of an infrared automatic cloth towel dispenser is provided below.



**Figure 1: Cloth Towel Dispenser**

Although, cloth towel dispensers have undergone major improvements in terms of hygiene, they are not very prominent in society. One reason for this may be due to the fact that in Canada in 2001 there were five cases of self strangulation deaths resulting from kids wrapping the cloths around their neck and hanging from them. These incidents were isolated and were results from playing games with these dispensers. All the incidents involved kids of 12 years of age and under. There were no documented self strangulation incidents with people older than 12 years old. Perhaps this is the reason we no longer see these dispensers in public washrooms anymore. However, with new designs large portions of cloth are no longer left hanging from the dispensers meaning that it is not possible for kids or adults to strangle themselves with these cloths. Although, there is some dark history to these dispensers, one must not discount them from alternative hand drying methods because they are indeed very sustainable as this report will show.



## 2.2 Environmental Impact

The cloth towel dispensers use long rolls of cloth towels as the medium in which you dry your hands.

These cloth towels are 100% reusable, after the roll has been completely used it must be washed and dried and can then be replaced into the dispenser. The energy consumption of this dispenser lies in the detection of the user, the motor supplying the user with an unused portion of towel and the washing and drying of the cloth towel rolls. As a result these systems generate very little waste to the environment. All the waste that is generated is the soap used to clean the towels as well as the energy expended to dispense and clean the towels.

In order to accurately calculate an estimate of the energy used by the system data has been acquired through various websites. A standard washing machine uses about 0.256 kWh per load and a standard dryer uses 0.22 kWh for heat and 0.21 kWh to spin the drum (How to, 2009). So for one complete washing and drying cycle a total of 0.686kWh would be used. One load of laundry would be able to clean approximately 40 cloth towel rolls, which means that for each roll one is expending 0.01715 kWh.

This means that in for every roll of cloth towel used in a washroom at UBC, 17 W will be used to clean it. This energy however is not based on an energy star rated washing machine. If a more efficient washer and dryer were used this number would be below 10 W. The energy used does not account for the dirty water produced by the washing machine. However finding a number of how much it costs to clean a load of soapy water is not readily available.

The above calculations assume that there is an onsite washing service in the SUB, otherwise these towel rolls would need to be transported to a washing service where they could be cleaned. This would increase the environmental impact of the product because we would then have to consider the effects of transporting the dirty towel rolls.

Studies shown on the Darman Manufacturing Company Inc. website display the direct solid waste benefits of using cloth towel dispensers instead of paper towels. The figure below shows the amount of solid waste in pounds produced for paper towels and cloth towels.



Figure 2: Solid Waste Impact of Hand TOWeling (Darman, 2009)

From an environmental aspect these towels seem to be a relatively good choice as the advantages of this system are easily observable:

- Reduces Waste (only waste product is soapy water from washing machine)
- Cloth towels can be reused over and over again
- Minimal energy consumptions (Washing and drying these towels consumes approximately 17 W per towel roll with inefficient machines)
- Promotes sustainability

### 2.3 Economic Impact

In order to analyse the economic impact of using cloth towel dispensers in the new SUB, this report will look at the money spent on the actual dispensers and cloths as well as the money spent on cleaning them.

Darman Manufacturing Company Inc. A cloth towel retailer lists each dispenser unit at \$109 for a manual retractable unit and \$209 for the automatic retractable unit. The new SUB project would be interested in purchasing the automatic retractable unit as it greatly reduces the number of bacteria on the users hand after its use. They also sell the cloth towel textile rolls at a price of \$18 per roll. The cloth towel rolls are 111 ft long and 11 in wide. Estimating over usage each user would use approximately 2 ft for every use. This means each roll will get approximately 56 uses. The company also lists the average lifetime of each roll to be about 200 washes this means that each roll would allow for 11200 uses over its full lifetime. Estimating about 5000 daily washroom users in the new SUB, the new sub would have to purchase approximately 100 cloth rolls to serve a full day of use. In order to be on the safe side and have ample supply of cloth towel rolls a purchase of 400 cloth rolls would be recommended. For more information on Darman products please consult their website <http://www.darmanco.com/index.asp>.

If the AMS decides to use cloth towel dispensers, a majority of the cost will be in initially investing in the cloth towels. In order to provide sufficient hand drying services for students, the AMS would probably purchase approximately 400 of these cloth towel rolls. This would ensure that there are a sufficient amount of cloth towels to cater to the demand of the new SUB users. This means that an initial outlay of \$7 200 would be required. Because the lifespan of these towels is approximately 200 washes, the AMS would have to replace 100 cloth towels every 200 days. This means that they would be spending approximately \$3400 a year on supplying hand drying towels to the new SUB.

In regards to the money spent on cleaning the cloth towels, data has been acquired from a saving electricity website (<http://michaelbluejay.com/electricity/>). The following tables denote the amount of money spent based on the settings to which the washer and dryer are set to.

**Table 1: Costs of Washing and Drying**

Total Cost per Load		
Washing Machine		
Wash/Rinse Setting	Electric Water Heater	Gas Water Heater
Hot/Warm	69¢	52¢
Hot/Cold	50¢	39¢
Warm/Warm	50¢	39¢
Warm/Cold	32¢	27¢
Cold/Cold	14¢	14¢
Dryer		
	36¢	34¢

(Bluejay, 2009)

Per load approximately 20 cloth towels would be able to be cleaned. Assuming a warm/warm washing cycle and electric water heating, the total cost to clean 20 cloth towels would be approximately 86¢. This means that for one cloth towel roll it would cost approximately 4.30¢ to clean. In order to provide reasonable approximate calculations for the comparison section of this report, an estimate that it costs \$1.50 for 20 towels to be washed and dried. This includes an expenditure on soap.

If the SUB washed 100 cloth towels a day for a year they would spend approximately \$784.75 on cleaning the cloth towels. If we had soap expenses we could approximate this value to be around \$1000. This means that for a full year of hand drying using cloth towel dispensers the AMS would spend \$4400. This is a relatively low yearly price to pay for yearly hand drying. Making the cloth hand towel a great competitor to other hand drying methods.

## **2.4 Social Impact**

Cloth towel dispensers have a variety of positive social impacts. If these dispensers would be used in the new SUB, jobs would be created as the SUB would need to hire people to clean the used cloth towels every day. With the use of reusable towels there would be a drastic reduction in the amount of waste produced by the SUB on a daily basis. This would elevate many trash disposal costs and reflect positively on the sustainability initiatives cast out by the New SUB project.

The cloth towel rolls provided by Darman Manufacturing are machined made in the U.S.A. This means that these products are not made in sweatshops and that they are paying their employees fair wages for their work.

The use of cloth towel dispensers would also have a positive effect on the users of the SUB. They would immediately notice that the two most common methods of hand drying are not being used because evidently the cloth towel is a more sustainable practice. This would be an easy self-advertisement of sustainability and would promote students to reduce their waste.

## **2.5 Hygiene**

Hygiene is one of the most important issues when looking at hand drying methods. Many studies have been performed relating the amount of bacteria on a person's hand after they have used a specific hand drying method. Luckily these studies do take into account the use of cloth towel dispensers in washrooms. These studies look at the percentage of bacteria taken away after each hand drying method. A study done in 1994 at the University of Westminster has been a benchmark for measuring the hygienic value of different hand drying in methods.

In this study they found that the number of bacteria present on the hands decreased by 42% on average when using paper, but by only 10% when using textiles and that it increased by 50% when using hot air driers (Redway et al, 1994). In another study performed by a German company found that there was "an average reduction of 24% in the number of most bacterial types present on the hands when using paper, as compared with a decrease of 4% for textiles and an increase of 117% when the hands were dried with hot air." (TÜV Produkt und Umwelt GmbH, 2005).

Studies presented on the Darman website show that cloth towels are a very close second to paper towels. The graph below displays the amount of bacteria left on the users hand after using the three different methods of hand drying presented in this report.

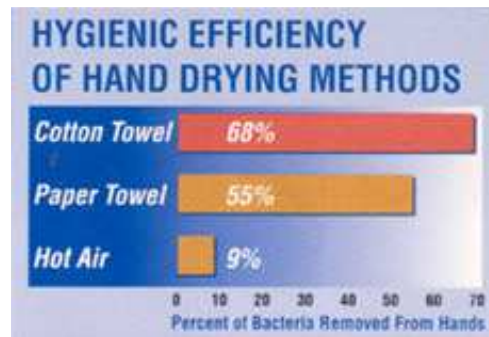


Figure 3: Hygienic Efficiency of Hand Drying Methods (Darman, 2009)

One must take into account that the cloth towel dispensers used in both these studies was not an automatic dispensing system. This means that the action of pulling down a used portion of cloth could mean that this action cause more bacteria to be present on your hands.

Either way it is evident that whichever method you use to dry your hands, no matter how hygienic you believe it to be, there will always be bacteria left on your hand. The only solution to this is offering users anti bacterial hand sanitizer once they have left the washroom.

### 3.0 Hand Dryers

Hand Dryers are electrical machines found in public washrooms and used to dry hands. They operate with a button or by infrared sensor. The creation of hand dryers were prompted by the need for an environmental friendly solution to hand drying. They remain attractive to users because they are eco-friendly, no trees killed and no trash. The following section will assess the different types of hand dryers to understand its social, economical and environmental advantages and disadvantages.

#### 3.1 How Hand Dryers are made

Inside the hand dryer, there are control circuit boards attached to infrared sensors. These sensors shoot a continuous beam to the area just below the air outlet, to detect a person's hand. The motor and blowing wheel is held by a rubber gasket to reduce vibration noise. The blowing wheel spins typically at a rate of 20,000 revolutions per minute. There is also an electrical heating element that heats the air as it passes through. The casing of the hand dryer is made of zinc and blushed with a buffer wheel so that it can be painted for a more pleasing appearance (Electric Hand Dryers, 2009).

#### 3.2 Conventional Hand Dryer

The conventional hand dryer is usually seen attached to the walls of public washrooms. The picture below shows a typical conventional hand dryer. The electrical specifications of the Extreme Air GXT Hand Dryer are described in Appendix 1.



**Figure 4: Extreme Air's GXT Hand Dryer**  
(from <https://caniandryer.com/files/file/Spec%20Sheet%20GXT.pdf>)

### 3.3 Case Study on Air Dryers

Compared to other hand drying means like paper towels or cloth dryers, hand dryers are shown to be more energy efficient because of less maintenance and no trash. It is simply purchase, install and use the product. However, its most considerable disadvantage is its health implications.

In a study done by the University of Westminster, they investigated the use of paper towels, jet air dryers and traditional warm air dryers as means of hand drying. They found that the total number of bacteria on finger pads after washing and drying with a paper towel was reduced by 76%, in contrast to an increase of 194% using a traditional warm air dryer, and an increase of 42% with a jet air dryer.

The study also examined the drying methods and revealed that the jet air dryer can blow micro-organisms from the hands and unit up to least 2 meters away, and the traditional warm air dryer can spread micro-organisms up to 25cm from the dryer, in both situations it creating contamination risks. The study concluded that paper towels should be used as opposed to air dryers in areas where hygiene is of paramount importance (Electric Hand Dryers, 2009).

### 3.4 New Generation Hand Dryer

The health implications of conventional hand dryers prompted the development of new generation dryers. These machines are attached lower on the wall so that hands are dried downwards and in an enclosed area. The picture below shows a typical new generation hand dryer.

The electrical specifications of the Dyson Air Blade are described in Appendix 1.



**Figure 5: Dyson AirBlade Hand Dryer**

(from <http://media.dyson.com/downloads/CAEN/airblade/pdf/brochure.pdf> )

### 3.5 Economic, Environmental and Social Impact

Facility managers consider two types of costs, monetary and time cost. The cost of a traditional hand dryer is around \$450, new generation hand dryer Veltia at \$700, and \$1400 for a Dyson AirBlade (Dyson, 2009). In terms of time, these dryers can dry hands in 10-15 seconds. These machines are installed and then utilized. The only maintenance needed would be a regular outside cleaning of the device. The energy use per dry varies for each device. The Dyson AirBlade uses 4.67Watt-Hours of energy for every dry, which is considered little in contrast to other drying methods that require regular delivery and maintenance.



The remaining factor to consider is the unit's lifetime, the number of times and the duration it can be used before the cycle repeats itself and the unit needs to be replaced. For the Extreme Air Hand Dryer, the lifetime is just over five years (GXT Hand Dryers, 2009) and the Dyson AirBlade at five years (Dyson, 2009).

### **3.5.1 Environmental**

The climate conservancy tested two average hand dryers used today: one drawing 2300 watts and another only drawing 1725 watts for 30 seconds. Each hand dryer emitted 12.1 grams and 8.9 grams of CO<sub>2</sub> respectively. Although these numbers seem small, the group had to keep in mind that these numbers are for a single use of one hand dryer. If we take into account the thousands of students that use the SUB each day, the amount out of CO<sub>2</sub> emissions increases dramatically.

A disadvantage to using hand dryers is the amount of bacteria left on one's hand after use. The University of Westminster did a study between hand dryers and paper towels. It showed that after drying one's hand with a warm air dryer the amount of bacteria on the palms increased up to 255%. This really worried the group in even considering recommending hand dryers as a hand drying method.

The great advantage of Hand dryers are that they call for very little to no regular replenishment or maintenance. After the machine has exceeded its lifetime, its components, the aluminum, steel and other materials should be properly recycled.

### **3.5.2 Social Impact**

A sample of people assert that using an electric hand dryer to dry hands is better than the other methods because it is the least harmful to the environment. Another sample prefers to use paper towels giving the reason that it is more sanitary. The reasoning both samples give are valid, hand dryers are energy efficient but they do pose hazardous health risks. The difference is that the second group has been educated with knowledge on the health implications of hand dryers, whereas the first group uses their own reasoning in making the decision to which hand drying method is better. One cannot help but notice that the majority of hospitals use paper towels and not hand dryers.

The Dyson AirBlade hand dryer is a new generation technology that was created to address the concerns with conventional hand dryers. This technology emerged late 2007, and there have been no outside studies done on the health implications on this specific brand.

## 4.0 Recycled Paper Towels

Paper towels are currently the dominant method for drying one's hands at UBC, and definitely the only method used at the existing Student Union Building (SUB). Although there are a few warm air dryers located around campus, most of them are worn out and old. Therefore, given the ubiquity of paper towels, there has to be some underlying rationale behind the use of this particular method of hand drying given UBC's commitment to sustainability.

This section will explore the purpose behind the use of paper towels by using a triple bottom analysis to carry out the task. First, environmental implications, both positive and negative, of using paper towels will be discussed, then an economic analysis of paper towels will be delivered, and finally, the social ramifications of using paper towels will be presented.

### 4.1 Environmental Implications

The UBC sustainability oath states "I pledge to explore and take into account the social and ecological consequences of my decisions. Furthermore, I pledge to use the knowledge I gain while at UBC to improve the sustainability of the communities in which I live, learn, and work."(UBC, 2007). Given that sustainability is such an important part of the UBC image, qualitatively and quantitatively analyzing the life-cycle of paper towels, both recycled paper and virgin paper, is of utmost importance.

First, analyzing the negative environmental effects of paper production has to be taken into account, since it is common knowledge that there are grave environmental effects of this process. Whether it is paper towel, toilet paper, or printing paper, all types of paper have the same production process and hence the same effects on the environment. Recycled paper towels originate from virgin paper which has been used, and recycled paper can only be used around 5-8 times(Georgia Tech, 2006) until virgin paper will to be produced again, therefore, this also calls for looking at the cost the environment pays due to virgin paper production in detail. Hence, this next sub-section will take a look at the ecological impact of paper production as a whole, and not specifically to production of paper towels.

#### 4.1.1 Deforestation

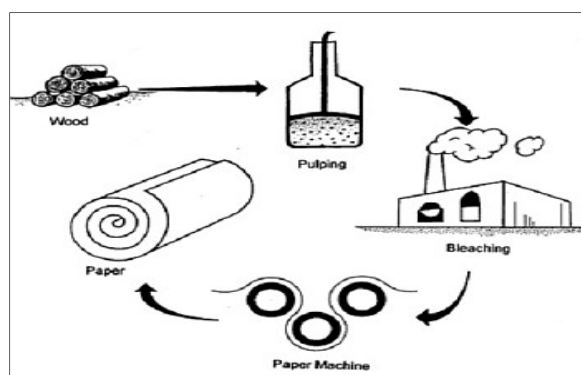
This is probably the most environmentally grave, albeit the fundamental step of paper production. Without cutting trees and using pulp derived from wood, there would be no paper, and as we all know, without paper there can be propagation of knowledge and with that there can be no progress in society. 35% of all harvested trees are used for the production of paper (Martin, 2008).

Deforestation is also one of the major contributors to the greenhouse effect, and according to the Intergovernmental Panel on Climate Change, accounts for one-third of total anthropogenic carbon dioxide emissions (Denman and Brasseur, 2007) . It is common knowledge that trees remove carbon dioxide from the atmosphere and through the process of photosynthesis, release oxygen back to the atmosphere. Forests greatly enhance the stability of the biosphere, and therefore reducing the amount of trees in the world has given rise to the increase of harmful green house gases, and this in turn has created the grave threat of global warming which has been recognized as danger which can cause many a problem in years to come.

Ecologically speaking, the negative effects of deforestation can also be seen in the decline of the earth's biodiversity. 80% of the world's known biodiversity is known to reside in tropical rainforests, and deforestation creates a damaged environment and diminished biodiversity. Scientists have estimated that we are losing about 50,000 species a year, and since biodiversity is often used as a measure of health of biological systems, we can see that the planet is losing its freshness and beauty very fast due to deforestation (Rainforest facts, 1996).

#### 4.1.2 Air Pollution

The process of the production of paper gives rise to the emission of gases such as Nitrogen Dioxide, Sulfur Dioxide, and Carbon Dioxide (CO<sub>2</sub>). Most of these gases are produced from paper mills from burnt pulp. The picture below shows the process of paper making. Again, CO<sub>2</sub> is recognized as a major greenhouse gas and contributor to global warming and the continuous use of paper towels will result in more of this harmful gas being emitted into the atmosphere. The paper making process can be seen in Figure 1 below.



**Figure 6: Paper making process**

Retrieved: <http://mevysa.files.wordpress.com/2008/12/pulp-paper-making-cycle66.jpg>

### 4.1.3 Water pollution

Pulp and paper mills release waste water containing solids, nutrients and dissolved organic matter all which can be classified as pollutants. These substances contain elements such as nitrogen and phosphorous which can cause or intensify eutrophication (an increase in the concentration of chemical nutrients in an ecosystem) of fresh water bodies such as lakes and rivers (Health Canada, 1991).

### 4.1.4 Wood pulping process

Lignin is a complex chemical compound derived from wood and delignification is the process of removing all lignin so that the pulp becomes brighter. However, delignification of chemical pulps releases considerable amounts of organic substances into the environment, especially into fresh water bodies such as rivers and lakes. Bleaching (another word of delignification) with chlorine produces a large amount of organochlorine compounds, including dioxins which are environmental pollutants (Health Canada, 1991).

### 4.1.5 Recycled paper

Recycled paper is naturally better than using virgin paper since it does not require more trees to be felled. There are 3 types of recyclable paper: mill broke, pre-consumer waste and post-consumer waste (Cheang, 2000). In this analysis the team will only look at post-consumer waste because it is this type of waste that is ultimately dumped into landfills, and since the increasing shortage of landfills makes this unfeasible, recycling used paper towels is a very serious step in conserving earth's natural resources.

Paper can only be recycled about 5-8 times (Georgia Tech. 2006) but post-consumer paper requires less energy to be recycled than virgin paper. The United States Environmental Protection Agency (USEPA, 2009) has found that recycling causes 35% less water pollution and 74% less air pollution than manufacturing virgin paper. In addition, modern mills produce considerably less pollution than older ones. Therefore, UBC, by using recycled paper made from Kruger, have been definitely doing their part in being sustainable.

However, recycling comes with a few major disadvantages as well. First, the gathering, sorting, baling, and transportation of waste paper means that this process is not emission-free, but this does not mean that there is an increase in green house emissions, which is beneficial. Cost-wise, recycled paper towel is actually cheaper than virgin paper towel (Cheang, 2000). In the analysis, below, it is assumed that recycled paper towels cost 75% of the price of virgin paper towel. As shown in the analysis in the next

part, transportation is quite a significant part of energy consumption in the paper towel cycle, and therefore, this is a heavy price to pay even before recycling starts

#### 4.2 Economic and Energy Analysis of Paper Towels

After conducting research on the internet the group found a very credible life cycle analysis of paper towels and hand dryers. The analysis was done by Rebecca Clarren of Salon.com which is an online news site affiliated with the National Geographic Channel. Clarren asked The Climate Conservatory, a non-profit organization established by scientists at Stanford University to inform those concerned about the green house gas (GHG) emissions embodied in the products they buy. Overall details of the calculations are as follows (Clarren, 2007):

**Table 2: Cost and amount of CO<sub>2</sub> emitted per one use of paper towels**

<b>Process</b>	<b>Cost per use(2 sheets of paper) (\$)</b>	<b>CO2 emitted per use (grams)</b>
Paper towel production	0.0157	14.02
Garbage bag production	0.00044	0.4532
Transportation of paper towels	0.00333	7.064
Transportation of Garbage Bags	negligible	negligible
Disposal of Paper towels	0.00451	32.99
Disposal of Garbage bags	0.000036	0.264
<b>Total</b>	<b>0.0240</b>	<b>54.79</b>

**Table 3: Numbers obtained if recycled towels are used**

Cost per use(75% of cost of virgin paper towel) (\$)	CO <sub>2</sub> emitted for recycling(74% less) (grams)
<b>0.018</b>	<b>13.1</b>

With these figures in place, and if one estimates that there are a total of 1000 visitors at the new SUB every day, then the total cost of that will be \$24, and the total amount of CO<sub>2</sub> emitted will be 54.79kgs, assuming every user pulls out paper towel equivalent to two standard 8"x8" sheets.

As we can see, 54.79 kg of CO<sub>2</sub> produced daily at the SUB has quite a negative impact on the environment. The group thought and realised that it is not wise to consider just recycled towels in the analysis since that would be obviously better than hand dryers. The initial amount of CO<sub>2</sub> has to be taken into consideration because without this amount there would not be any recycled paper towels. After the first use though, recycled paper towels are quite similar to hand dryers in terms of energy consumption.

In contrast, if the EIO-LCA method is used for hand-dryers (Carnegie Mellon), the maximum amount that can be emitted per use is 40g, and the minimum is 9g. Therefore, if we assume again that there are 1000 uses every day, that will amount to a maximum of 40kg of CO<sub>2</sub> emitted, which is much lower than the amount produced by paper towel usage. Appendix 2 shows the exact calculations obtained from the study by Clarren.

It does appear that hand dryers win the battle of supremacy when it comes to looking at which method has the lighter environmental footprint. However, another important aspect of the paper towel vs. hand dryer analysis which has to be taken into consideration is how hygienic both methods are, i.e. how efficient are they in terms of wiping off bacteria from one's hands. This part will be dealt with in more detail in the comparison section of the report, but a brief focus on the importance of hand drying with regard to reduction of bacteria on the hands will be discussed in the next section.

#### **4.2.1 Changes in the number of bacteria on the hands**

A recent study conducted by researchers Keith Redway and Shammeen Fawdar at the University of Westminster explores the efficacy of three hand drying methods: paper towels, warm air dryers, and jet air dryers, in great depth (Redway and Fawdar, 2008). It is a common fact that proper hand hygiene plays a critical role in reducing the spread of disease and anti-biotic resistant bacteria in hospitals, and in the public, therefore looking at the numbers before and after washing and drying of hands does serve as a very important measure in determining which method would be best for the SUB.

The hand drying materials used for each method in this study were as follows:

Paper Towels:

- Paper Towel 1(PT1): 2 ply 100% recycled
- Paper Towel2(PT2): 2 ply 100% virgin

- Paper Towel3(PT3): 2-ply through-air dried- 50% virgin, 50% recycled
- Paper Towel4(PT4): 1-ply 100% recycled
- Paper Towel5(PT5): 1-ply 100% recycled

#### Hand Dryers:

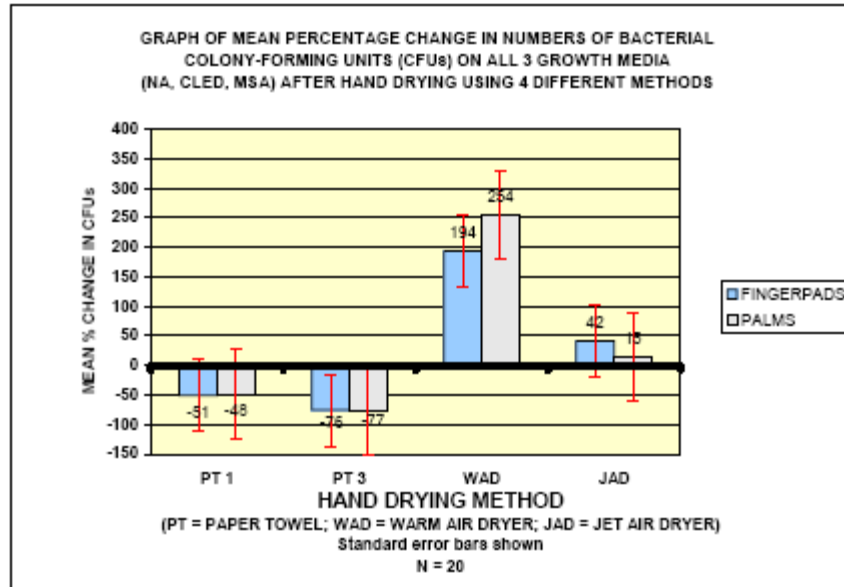
- Warm Air Dryer(WAD) – Electric Aire, Model LE48
- Jet air Dryer(JAD) – Dyson Airblade

A concise outline of the method that Redway and Fawdar used is as follows:

1. 10 male and 10 female subjects were asked to visit a public washroom and return to the laboratory without washing their hands
2. Three different agar growth media were used to sample the dominant hand of each user before washing and drying (BD) and after washing and drying (AD).
3. Critical areas of the hand were sampled: fingerpads and the palm
4. Subjects were asked to wash and rinse their hands for 10 seconds(s) with one use of liquid soap and then dry them using PT1(10 s), PT3(10s), WAD(20s) or JAD(10s). No instructions were given on how to dry their hands
5. The hand areas sampled in 3 were sampled again
6. Agar plates were incubated at 37deg C and inspected after 1 and 2 days for bacterial growth.
7. Results were recorded and statistically examined. The results are shown in the Table below.

**Table 4: Reduction of bacteria from 4 different drying methods**

GROWTH MEDIUM	COLONY TYPE	PAPER TOWEL 1 (PT 1)	PAPER TOWEL 3 (PT 3)	WARM AIR DRYER (WAD)	JET AIR DRYER (JAD)
NA	ALL	-44.6 ↓ *	-76.9 ↓ ***	+186.4 ↑ ****	+52.8 ↑ **
CLED	ALL	-53.4 ↓	-70.5 ↓ **	+204.3 ↑ ****	+28.0 ↑
MSA	MAN +	-58.5 ↓	-91.5 ↓ *	+414.0 ↑ ***	+193.3 ↑ **
MSA	MAN -	-56.6 ↓ **	-68.3 ↓ **	+114.1 ↑ **	-8.4 ↓
MSA	ALL	-57.3 ↓ **	-77.4 ↓ **	+191.0 ↑ ****	+45.8 ↑ *
TOTAL	ALL	-51.4 ↓ *	-75.6 ↓ ***	+193.9 ↑ ****	+42.0 ↑ *



**Figure 7: Bar chart showing change in number of bacteria after drying hands**

The 2008 study shows palpably (Redway and Fawdar, 2009) that paper towels do a superior job in bacteria removal compared to the WAD and the JAD. However, one could argue that if the JAD was used a bit longer, then bacteria would decrease slightly more. But using a hand dryer for longer would mean greater energy consumption, and if they are solely used, then that number would be even higher.

Therefore, with this comparison it becomes clear that paper towel 100% recycled or 50% virgin/50% recycled should be used solely on the basis of hygiene, and this is quite a huge find since this will greatly influence whether the group will choose to recommend hand dryers or not.

It has been stated that paper production contributes to global warming and that hand dryers have an advantage in the which-method-has-a-lighter carbon footprint debate given that they only use electrical energy. However, if one looks deeper into the situation, the Westminster shows clearly that the bacterial levels shoot up after washing hands with the JAD. There is already a current panic with the spread of H1N1 and bacteria allowed to multiply and transmit from person to another does not help society at large. With this in mind, the group has to take a serious look at what would be best for users of the new SUB's washrooms: the energy efficiency of hand dryers, or the reduction in amount of bacteria on people's hands.

It is worth mentioning that paper production amounts to only about 15% of GHG emissions, while the other 85% comes mainly from transport vehicles and industrial factories. Does it make sense to try and



reduce the 15% worth of emissions while compromising on human health? The group decided that it would have to be cognizant of this when recommending their choice to the final report.

### **Societal Impact**

Paper towel use in the new SUB will mean that the janitors will have to continue to do their work in replacing rolls in dispensers and cleaning out the garbage at regular times. They will have a considerable amount of work to do, and the number of them will also remain the same. The truck drivers who bring paper towels cases to the SUB will also still have work since a regular supply of paper will always be needed. This would mean that they also have their job of driving to UBC on a regular basis and get their wages on the number of hours they have worked.

Also, if UBC uses recycled paper, then those drivers who drive to collect waste paper and take them back to the recycling factories will still have their jobs. Since recycling is a labour-intensive process, those people employed to sort and bale will still have their source of income.

On the other hand, if the SUB uses hand dryers, then there will definitely be no need for the number of janitors currently at the SUB as well as those involved heavily with the recycling process. There will not be huge garbage bags to be packed everyday and no need for replacing rolls. Also, drivers bringing paper towels to UBC will lose driving hours and hence will have reduced wages.

Paper towels then do have an impact, although not a very significant one, on society. But the question still remains, is the UBC community more interested in saving the jobs of people of protecting the environment from deadly green house gases?

## 5.0 Comparisons

Using the triple-bottom-line method of analysis, comparing the three methods of hand drying was categorised into environmental effects (electrical power consumption, hygiene levels, and emission of CO<sub>2</sub>) economical costs, and social impact. The evaluation of which hand drying method should be used at the new SUB was difficult because each member researched a different means of hand-drying, each of which has positives and negatives which have to be analyzed before an educated decision is made. The team took a look at how UBC has currently setup their hand dryers. The majority of the hand-dryers on campus are paper towel dispensers with a few warm air dryers scattered around some building around campus. The important question is why have are paper towels and hand dryers seen around campus instead of just one. The only conclusion that the group came up with after looking at how old the warm air dryers looked was that they had been installed before paper towel dispensers were installed at other washrooms. The reason for this change of hand-drying method was taken into account when looking at the comparisons and making our final decision, and as mentioned in an earlier section, there has to be a significant underlying reason as to why paper towel dispensers were chosen as the preferred hand drying method

### 5.1 General Hygiene

It is common knowledge that the effectiveness of the removal of bacteria is one of the most important factors in choosing which drying method should be used. With the ever increasing evolution of antibiotic resistant bacteria, it is vital that when drying our hands, we destroy as much bacteria as possible. If any of the drying methods were to increase the amount of bacteria on the hands, they would be immediately ruled out.

A number of studies conducted on the effectiveness of hand-drying methods with regard to hygiene show that after drying one's hands with warm air hand dryers, the bacteria count increases by up to 254% on palms and 194% on finger pads (Table 2). The reason behind this is that when drying your hands with warm air dryers, most of the microorganisms are not killed. The warm and hot air dryers only evaporate the water on the hands and the air is not hot enough to eliminate all microorganisms and thereby reduce the risk of transmission of possibly harmful bacteria. . When it came to cloth dryers and paper towels, the results on the amount of bacteria removed was quite similar. Cloth towels removed on average 45% the bacteria while paper towels removed about 58% as shown in Figure 8 (European Tissue Symposium, 2009). The findings are very similar to the study done at the University of Westminster.

The only concern that was brought up with using cloth towels and hand dryers was whether or not to have a motion sensor dispenser to lower the likelihood of cross contamination when pulling for the clean and

unused cloths or paper towels. This would of course change the cost of both the cloth dispensers and paper towel dispensers

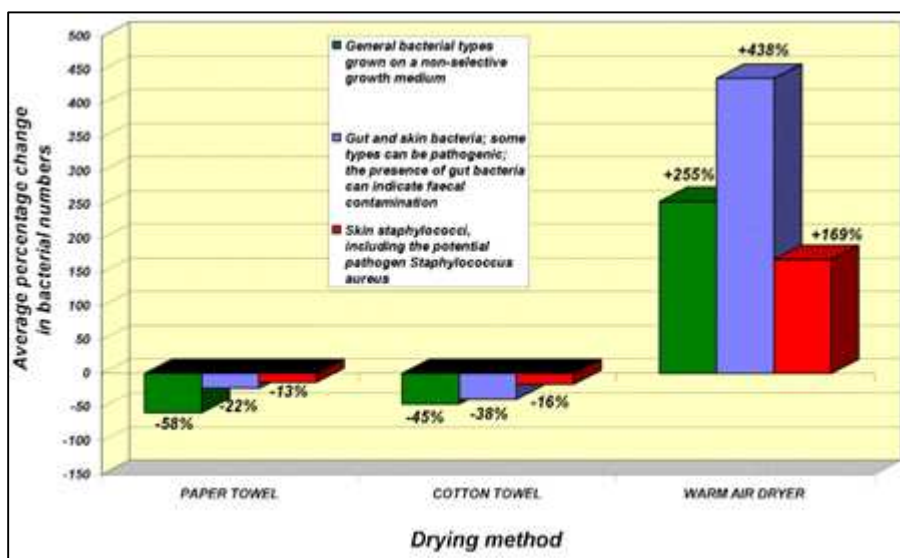


Figure 8: Changes in the amount of bacteria after each type of hand-drying method used

The above figure clearly shows that bacteria are greatly reduced when the paper towel and cloth towel methods are used. However, the warm hair dryer is quite abysmal in terms of killing bacteria. The JAD, as shown in Figure 7 does is more hygienic than the WAD, but not nearly as good as paper towels or cloth towels.

## 5.2 Economical Costs

When looking at the costs of drying methods, more than just the cost of procurement needs to be taken into consideration. Each hand dryer has its own unique list of expenses, a comparison of which could, in turn, make the group favour the one less costly and thereby influence the final decision. Yearly costs were calculated based on the assumption that 2000 users would use the selected hand drying method daily. The table of yearly expenditures is provided below.

Table 5: Cost comparison for installation and maintenance in first year with one unit

Hand drying method	Cost of acquiring a new unit	Cost per new Roll/unit	Cost of maintenance(\$)	1 <sup>st</sup> Year Initial Expenditure for 2000 users/day
Paper towel	\$150/automatic dispenser	\$2.75	0.024 per use of 2 towels	\$17670
Cloth Towel	\$209/ automatic dispenser + 2 replacements*\$18*40 towels = \$1440	\$18	\$3 per 40 cloth towels washed and dried	\$2744
Hand Dryer	\$1400 for Dyson Airblade	Depends on unit	0.0028 dollars/use	\$3444

The table above shows a huge difference in yearly costs of operating a paper towel dispenser versus both cloth towel dispensers and hand dryers. The yearly of expenditure for paper towels is so high because paper towels must constantly be repurchased in order to supply the demand of the new SUB. On the other hand the yearly expenditure for cloth towels is so low because the low daily operating costs of cleaning the towels. Although the initial outlay for cloth towels is high and they must be all be replaced halfway through the year because their average life expectancy is 200 washes. The hand dryer yearly expenditure is also low because of the lack of any additional purchases. Once the unit is purchased you are simply paying for the energy used per use. We have neglected the cost of electricity to run the automatic dispensing systems for both the paper towel dispensers and the cloth towel dispensers because this cost would be low and is difficult to approximate. However, giving a very generous approximation of \$200 yearly cost, cloth towel dispensers would still cost less than hand dryers in terms of yearly expenditure. Finally, one must realize that we are approximating 2000 uses on one unit, so the initial outlay for units is just the cost of one. In reality there would probably be approximately 50 of these units in the new SUB. This means that the initial expenditure for the paper towels would be relatively similar. The hand dryer on the other hand would be much larger. An approximate cost table has been provided below based on an initial purchase of 50 units.

**Table 6: Cost comparison for installation and maintenance in first year with 50 units**

<b>Hand drying method</b>	<b>Cost of acquiring 50 new unit</b>	<b>Cost per new Roll/unit</b>	<b>Cost of maintenance(\$)</b>	<b>1<sup>st</sup> Year Initial Expenditure for 2000 users/day</b>
<b>Paper towel</b>	50*\$150=7500	\$2.75	0.024 per use of 2 towels	\$25170
<b>Cloth Towel</b>	50*\$209/ automatic dispenser + 2 replacements*\$18*50 towels = \$1440	\$18	\$3.75 per 50 cloth towels washed and dried	\$13618.75
<b>Hand Dryer</b>	\$50*\$1400 for Dyson Airblade	Depends on unit	0.0028 dollars/use	\$72044

The table above still shows the cloth towel dispensers as a winner in terms of 1<sup>st</sup> year of implementation expenditure. Once again this is because of the low cost of washing and reusing the cloth towels. However, this table is still skewed because the hand dryers have a huge initial outlay but after the first year there are no more expenditure on new units. In order to provide an even more accurate cost estimate, we looked at a 15 year period of use of each hand drying method. The table below looks at the total expenditure over a 15 year period including the 1<sup>st</sup> initial expenditure year.

Table 7: Cost comparison for installation and maintenance in first 15 years with 50 units

Hand drying method	Cost of acquiring 50 new unit	Cost of maintenance(\$)	1 <sup>st</sup> Year initial Expenditure for 2000 users/day	15 year expenditure (including initial)
Paper towel	50*\$150=7500	0.024 per use of 2 towels	\$25170	\$270300
Cloth Towel	50*\$209/ automatic dispenser + 2 replacements*\$18*50 towels = \$1440	\$3.75 per 50 cloth towels washed and dried	\$13618.75	\$57981.25
Hand Dryer	\$50*\$1400 for Dyson Airblade	0.0028 dollars/use	\$72044	\$100660

The table above still uses the same approximations as the last two tables however because we look at a period of 15 years the costs of operating each method is much more accurate. One should also note that these cost estimates do not include the amount of money spent on maintenance and cleaning of the units. We can assume that the maintenance and cleaning costs of all three methods will be approximately the same. As a result we can see that the cheapest option is the cloth towel dispenser which is about half the cost of the hand driers. The paper towel dispensers have the largest cost about 3 times greater than that of the hand drier. It is clear that in terms of economic analysis that cloth towel dispensers are the best choice.

### 5.3 Environmental Effects

Comparing the environmental effects of all three hand drying methods was probably one of the hardest sections of the research report. Finding environmental effects for each method was not hard, but quantifying them posed a big challenge to the group. However, after diligent research, the group did find a number of sources that outlined how each hand-drying method affected the world in terms of the amount of CO<sub>2</sub> emitted; the findings have been presented in the earlier sections of the report and the information will be presented side by side for a critical analysis. The problem that the group will face will be to choose which method contributes more towards sustainability in terms of leaving a smaller ecological footprint while being aware of the facts of hygiene levels offered by each method after use. Table 4 below shows the numbers obtained for the three methods in terms of electrical energy consumed in kWh, and CO<sub>2</sub> emitted in grams per one use.

**Table 8: Electrical Energy consumed and CO<sub>2</sub> emitted per use of hand drying method**

Method of drying Per use	Wh consumed	CO <sub>2</sub> emitted (grams)
Cloth Towels	0.5	30
Paper Towels	0.6	56
Hand Dryers	4.67	25

As we can see from Table 7, hand driers have the lowest CO<sub>2</sub> emitted per use. This is because it only uses electrical energy which must be obtained from local community power plants. The other two methods have higher CO<sub>2</sub> levels because they take into consideration the disposal methods of the old/used paper and cloth towels. The paper towels must be collected in plastic bags and then recycled and remade into paper towels. This also involves transportation of the new and used paper towels to and from the production, recycling and user sites. The cloth towel CO<sub>2</sub> levels are based on the incineration of the old towels after 200 washes. The estimate also considers the transportation of the cloth towels to and from the incineration and the user sites. Next we must look at the Wh used each hand drying method. The hand drier has a relatively high Wh usage because it uses quite a bit of energy to dry hands. The cloth and paper towel dispensers have a low Wh consumption because they simply require energy to sense a user and turn a motor to dispense new unused towels. This means that the sensors and motors are only used for a limited amount of time per use. The cloth and paper towel values also consider the amount of energy used to recycle/manufacture the product. In order to provide an even more accurate comparison a 15 year analysis will be made based on each method, this table is provided below.

**Table 9: Electrical Energy consumed and CO<sub>2</sub> emitted for 15 years of operation**

Method of drying For 2000 uses per day for 15 years	MWh consumed	CO <sub>2</sub> emitted (kg)
Cloth Towels	5.475	328500
Paper Towels	6.408	613200
Hand Dryers	51.1365	273750

From the table above it is clear that hand driers produce the least amount of CO<sub>2</sub> emitted but uses the most amount of energy. The cloth towels adds approximately 50 000 kg more CO<sub>2</sub> than the hand drier but uses 46MW less than the hand drier. The worst option is by far the paper towels which adds almost double the amount of CO<sub>2</sub> into the atmosphere than the cloth towels and uses 1MW more than cloth

towels over the course of 15 years. If we balance the two categories the cloth towels are a very close competitor with the hand driers.

Considering the increasingly wasteful amount of paper towel which ends up as disposal, the negative environmental impact paper towels make is undeniable. Compared to the more environmentally friendly substitute such as the warm air dryer and cloth towel dispensers, paper towels appear to be the worse choice out of the three. In order to pick the better solution between cloth towels and hand driers, one must balance the option between using more energy or releasing more CO<sub>2</sub> into the atmosphere. This is a relatively hard comparison because our team cannot deduce which option does society think is more important. However, considering global warming relating to CO<sub>2</sub> being released into the atmosphere we will give the advantage to hand driers even though there is only a 50 000kg difference between the two, which is a relatively low difference.

## 6.0 Conclusion

After conducting comprehensive search on three methods of hand drying, the group had to come up with a decision on which method to recommend to the designers of the new SUB. A triple-bottom line analysis method was used to compare each hand drying alternative for their environmental, social and economical impacts.

Based on the comparison in the previous section, it is clear that in terms of environmental considerations, paper towels are the worst in terms of the amount of CO<sub>2</sub> emitted into the atmosphere. A very large number of 56 g of CO<sub>2</sub> emitted per use of 2 towels is deemed to be too extreme compared to the more moderate numbers of 25g and 30g emitted from hand dryers and cloth towels respectively. Cloth towels obviously do not emit gases in use, but the amount of gaseous products emitted during manufacture has to be taken into consideration; this is the same with paper towels. With hand dryers winning in terms of being the most environmentally friendly based on CO<sub>2</sub> levels. However, hand dryers failed to in the energy consumption category. They consume 10 times more energy than both of the other methods. This caused a deliberation in terms of which product wins in terms of sustainability. As a result, hand dryers and cloth towel dispensers tied in terms of their environmental impacts.

Economically, by taking cost of installation and maintenance over to a 15 year period into account, hand dryers need \$100,660 to be kept in good working condition. Paper towels, again, require a huge amount of \$270,300 to provide to the hand-drying needs of the 2000 users who will use the new Student Union Building's washrooms every day. That is a very large amount of money, and another undesirable effect that comes with it is the large number of used paper towels that have to be taken for recycling. Cloth towels, however, require only a modest amount of \$57,981 to keep the student body that visit the washrooms satisfied with clean, dry hands. With these numbers in mind, cloth towel dispensers clearly have the upper hand in terms of economic sustainability as well.

The results of studies that the group have presented make it obvious that hand dryers are inferior to cloth towels and paper towels when it comes to bacteria removal from users' hands. The general result was that warm hand dryers actually increase bacteria by anywhere from 168% to 438% depending on which area of the hand is sampled. These numbers are around 80% smaller for a jet-air dryer, but the amount of bacteria does still increase. Paper towels and cloth towels decrease the bacteria count by around 13% to 58% and therefore are pretty even on this competition. Modern day society needs to be wise about the spread of germs given the threat of viruses such as H1N1 and therefore, no chances should be taken in this matter.

On the last category of the triple bottom analysis, the social impact of hand dryers would mean that a lot of workers involved in the paper making and recycling process would lose their jobs and hence a means to support their families.

The same would happen if cloth towels were chosen over paper towels as the primary method of hand drying at the new Student Union Building. Recycling paper is a labour intensive process, with truck drivers having to come to the University to gather the used paper before baling them and having them



ready for the renewal process. Therefore, with cloth towels all these labourers' jobs would be lost. However, the Student Union building would require workers to wash towels and therefore the existing janitors who clean the garbage bins of the paper towel could wash towels. If recycled paper towels continue to be used, then there would be no change to the lives of people involved in the process.

The group now have all of the information to make a sound recommendation to the planners of the new Student Union Building. Given everything that was considered, cloth towels were found to be the most reasonable solution in terms of cost analysis; they also were equal to paper towels in terms of being hygienically superior to hand dryers. Moreover, and quite importantly, they also produced the low emissions of Carbon Dioxide. The use of cloth towels would also enable the existing janitors of the SUB to keep their jobs. The group reasoned that paper production would not reduce significantly with using cloth towels, and therefore the people involved in the process of paper production would still have their jobs for quite a while.

It is with confidence that the group recommends cloth towels as their final choice of hand drying method for the new SUB. UBC needs a change, and a reduction of wastage of paper, and a reason for them to say with conviction that they are truly committed to a more sustainable future.

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## Appendix 1

### Specifications for Extreme Air GXT Hand Dryers

Data from <https://canadiandryer.com/files/file/Spec%20Sheet%20GXT.pdf>

<b>Parameter</b>	<b>Data</b>
Casing	Steel
Rated Power	1500 W / 12.5 A
Input Voltage	110 – 120 V at 50/60 Hz
Motor Speed	24,000 RPM at 5/8 HP
Air Velocity	16,000 linear feet per minute
Air Temperature	135 d F at 72 d F Ambient
Sound Level	83 dB
Shipping Weight	5 kg
Energy Use Per Drying	51 kJ
Drying Time	10-15 seconds

### Specifications for Dyson AirBlade Hand Dryer

Data from <http://www.english.dysonairblade.ca/specification/>

<b>Parameter</b>	<b>Data</b>
Casing	Die Cast Aluminum

Rated Power	1400 W / 12 A
Input Voltage	120 V AC / 60 Hz
Motor Speed	81,000 RPM
Energy Consumption Per Dry	4.67 Watt-hours
Standby Power Consumption	1 W
Casing	Die Cast Aluminum
Air Speed at Nozzle	6440 km/h

## Appendix 2

### PAPER TOWELS VS. ELECTRIC HAND DRYERS

Rebecca Clarren of Salon.com asked TCC to help with some math on whether electric hand dryers or paper towels should be preferred by climate conscious consumers for a story published November 12, 2007:

#### **Public bathroom dilemma: Paper or air?**

The Kyoto protocol recognizes six gases that contribute to global warming: carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), perfluorocarbons (PFCs), hydrofluorocarbon (HFCs) and sulfur hexafluoride (SF<sub>6</sub>). To avoid everyone having to re-take chemistry, each of these gases is referenced to CO<sub>2</sub> by its global warming potential (GWP). For instance, methane has a GWP of 23 to carbon dioxide's one. The summation of these values has become a standard and is known as CO<sub>2</sub> equivalence or CO<sub>2</sub>e.

In order to determine the CO<sub>2</sub>e output of drying one's hands with two paper towels or using one or two blasts from a hand dryer, we need to understand the respective life cycles of paper towel use and the amount of energy used to run a typical hand dryer.

The process flow of energy and materials related to use of a hand dryer is as follows:

- Create electricity

That's pretty much it. More about our definition of the system boundaries appears below<sup>[1]</sup>.

The process flow of energy and materials related to paper towels is as follows:

- Logging/Recycling
- Pulp processing/Paper milling
- Refine oil to plastic for garbage bags
- Manufacture garbage bags
- Transport paper/garbage bags
- Disposal of paper/garbage bags

#### The Footprint of a Hand Dryer:

We considered two hand dryers: one drawing 2300 watts and the other drawing 1725 watts, each running for 30 seconds. There are dryers on the market that claim to use either less power or dry hands in a shorter time (e.g. the Dyson Blade). We chose to look at the average hand dryer in the US today, even though these redesigned dryers may be a great way

to conserve energy.

Based on an average distribution of fuels used to generate electricity in the U.S., a 2300 W dryer running for 30 seconds would account for 12.1 g CO<sub>2</sub>e emissions. If you hit the button twice, as I sometimes do, you'd double your value to 24.2 g CO<sub>2</sub>e. A 1725 W dryer calculated similarly would be 8.9 – 17.8 g CO<sub>2</sub>e. The calculations are as follows:

$$0.019 \text{ kWh} * 636.3 \text{ g CO}_2\text{e /kWh} = 12.1 \text{ g CO}_2\text{e}^{[2]}$$

Hit the button twice: 24.2 g CO<sub>2</sub>e

Or by an EIO-LCA method:

$$2.3 \text{ kW} * 0.0083 \text{ hours} \text{ is } 0.019 \text{ kWh} * .1009 \text{ \$/kWh}^{[3]} = .0019 \text{ dollar/use} = 19.95 \text{ g CO}_2\text{e}$$

Hit the button twice? = .0038 dollar/use = 39.90 g CO<sub>2</sub>e

For the lower wattage dryer:

$$0.014 \text{ kWh} * 636.3 \text{ g CO}_2\text{e /kWh} = 8.9 \text{ g CO}_2\text{e}$$

Hit button twice? = 17.8 g CO<sub>2</sub>e

Or by the EIO-LCA method:

$$1.725 \text{ kW} * 0.0083 \text{ hours} \text{ is } 0.014 \text{ kWh} * .1009\text{\$/kWh/use} = .0014 \text{ dollar/use} = 14.7 \text{ g CO}_2\text{e}$$

Hit the button twice? = .0028 dollar/use = 29.4 g CO<sub>2</sub>e

So if you walk into an average bathroom and use an average hand dryer in an average way, you'll be emitting anywhere from 9 – 40 g CO<sub>2</sub>e depending on the calculations and the type of dryer.

### A Tale of Two Towels

Calculations for paper are a bit harder because of the greater number of inputs:

#### *Paper Towel Production*

According to the EIO-LCA model of the Green Design Institute at Carnegie-Mellon (which is in turn based the US Department of Commerce's Input-Output tables), each dollar's worth of paper produced results in 892 g CO<sub>2</sub>e <sup>[4]</sup>.

Thus, \$33/case divided by 12 rolls/case divided by 350 sheets/roll <sup>[5]</sup> \* 2 sheets = .0157 dollar/use

$$892 \text{ g CO}_2\text{e} / \text{dollar} * .0157 \text{ dollar/use} = 14.00 \text{ g CO}_2\text{e}$$

### *Garbage Bag Production*

Again using the figures of the EIO-LCA model, a dollar's worth of plastic garbage bags cause roughly 1030 g CO<sub>2</sub>e to be emitted<sup>[6]</sup>.

$$1030 \text{ g CO}_2\text{e} / \text{dollar} * 0.00044 \text{ dollar/use} = 0.45 \text{ g CO}_2\text{e}$$

(We assume 24" X 24" light weight commercial trash bags @ 22\$ per carton of 1000 bags each = 0.022 dollars/bag divided by 50 uses/bag (of two towels each) = 0.00044 dollars/use<sup>[7]</sup>).

### *Transportation of Paper Towels*

The EIO-LCA method indicates the GHG intensity of shipping by truck is 2120 g CO<sub>2</sub>e /dollar<sup>[8]</sup>.

$$2120 \text{ g CO}_2\text{e} / \text{dollar} * 0.0033 \text{ dollar/use} = 7.00 \text{ g CO}_2\text{e}$$

(We assume 10 cases of 12 rolls of 350 towel sheets costs \$69.97 to ship<sup>[9]</sup>. Therefore, the shipping cost of two towels (one use) is \$0.0033)

### *Transportation of Garbage Bags*

Because one 4.1 kg carton of 1000 garbage bags would satisfy the needs of one commercial restroom for perhaps an entire year, we assume the transportation of the garbage bags to be negligible.

### *Disposal of Paper Towels*

According the EIO-LCA model, 7310 g CO<sub>2</sub>e are emitted per dollar of waste management and remediation services<sup>[10]</sup>. This large number is related to the production of methane through anaerobic decomposition of waste in landfills. Note that while some paper towels may use recycled material in their production, the used towels themselves are not recycled.

$$7310 \text{ g CO}_2\text{e} / \text{dollar} * 0.0045 \text{ dollar/use} = 32.90 \text{ g CO}_2\text{e}$$

(We assume landfill disposal rate of \$0.88/kg, one case of towels is 10.77 kg, one roll of towels is 0.898 kg and one use (two towels) is 0.0051 kg. Therefore the disposal of one use costs \$0.0045.)



### *Disposal of Garbage Bags*

$$7310 \text{ g CO}_2\text{e /dollar} * 0.00004 \text{ dollar/use} = 0.26 \text{ g CO}_2\text{e}$$

(We assume landfill disposal rate of \$0.88/kg, one case of bags is 4.1 kg, one bag is 0.0041 kg and the fraction of a bag for one use (two towels) is 0.000041 kg. Therefore the disposal of one use costs \$0.00004).

### Bottom Lines

As stated above, if you walk into an average bathroom and use an average hand dryer in an average way, you'll be causing somewhere between 9 – 40 g CO<sub>2</sub>e emissions. If you use two towels, data suggests you will be responsible for roughly 56 g CO<sub>2</sub>e emissions.

So, if you're not willing to use your pant leg, your best bet is an efficient dryer and, if one is not available, go for one towel (28g CO<sub>2</sub>e) only.

## **Division of Work**

Abstract – Sherry

Formatting – Aaron and Jian

Background and Motivation - Adrian

Cloth Towel Dispensers – Adrian

Hand Dryers – Sherry

Paper Towels – Aaron

Comparison – Jian and Adrian

Conclusion – Jian and Aaron

Final Edits – Adrian, Aaron and Jian