CZECH UNIVERSITY OF LIFE SCIENCES – PRAGUE

Faculty of Environmental Sciences

BACHELOR THESIS

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CZECH UNIVERSITY OF LIFE SCIENCES, PRAGUE

Faculty of Environmental Sciences

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Benefits of Electric Hand Dryers vs Paper Towels in Public Restrooms

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BACHELOR THESIS ASSIGNMENT

Connor Smith

Environmental Engineering

Thesis title

Benefits of Electric Hand Dryers vs Paper Towels in Public Restrooms

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Objectives of thesis

The objective of this thesis is to assess the current usage of paper towels vs electric hand dryers in public restrooms located in the Faculty of Environmental Science buildings, located on the campus of Czech University of Life Sciences. The research hypothesis is that there is a perceived difference as to the environmental and economic impact of both systems by the consumer (students, teachers and staff). The consumer, in theory, assumes that the presence of state of the art hand dryers (Dyson style that vacuum moisture off the hands) suggests that the business who installs these are promoting environmentally friendly technology and reducing paper waste. However, this theory has not yet been tested to determine if the hypothesis is in fact true, nor is there definative research to compare the real-world cost/benefit of the two systems; electronic hand dryers vs conventional paper towels.

This thesis will discuss other studies done to determine the sanitary conditions of both hand drying methods, the amount of electricity consumed, and the amount of paper towels used. Also to be explored are the difference in the electric hand dryers, and also the difference in the types of paper towels. This data will be used to determine the more sustainable and economically prudent method for hand drying in public restrooms.

Methodology

In addition to a review of published literature and industry manuals that specify operation of electronic hand dryers, the student will create a website to host an online survey that can be accessed by visitors to the many different restrooms in the Faculty of Environmental Sciences. The respondent will access the survey by scanning a QR code that is located on small posters placed in each of the restrooms in the FES faculty building (D and Z) on the CULS campus. This survey will allow data to be gathered to then evaluate user preferences for different hand drying choices in each restroom.

The proposed extent of the thesis

50 pages

Keywords

hand dryers, paper towels, public restrooms

Recommended information sources

Henderson, S. 2019. What's better for the environment, using a hand dryer or paper towels? https://www.newscientist.com/lastword/mg24232330-900-whats-better-for-the-environment-using-a-hand-dryer-or-paper-towels/

Jinyu, He. 2021. Are hand dryers better than paper towels for the environment? https://www.ceibs.edu/new-papers-columns/20636

Subramanian, S. 2019.Hand dryers v paper towels: the surprisingly dirty fight for the right to dry your hands. https://www.theguardian.com/society/2019/apr/25/hand-dryers-paper-towels-hygiene-dyson-airblade

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The Bachelor Thesis Supervisor

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Electronic approval: 21. 2. 2023

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Electronic approval: 27. 2. 2023

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Dean

Prague on 28. 03. 2023

DIPLOMA THESIS AUTHOR'S DECLARATION

I hereby declare that the work presented in this thesis, to the best of my knowledge, is my independent original work, under the supervision of Peter Kumble. I have listed all literature and publications from which I acquired information.

27.03.2023

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Connor Smith

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Abstract

This thesis investigates the environmental and economic impacts of electric hand dryers versus paper towels in public restrooms, and how the public views said impacts. As hand drying is an integral part of the hand washing process, the effects each method has on land use, emissions, water and air pollution, etc. needs to be studied and the most sustainable process achieved.

Incorporating evidence from previous studies and a completed public survey in university restrooms, this thesis shows that electric hand dryers are the more economically and environmentally optimal method to implement into public restrooms with lower costs and relatively less ecological effects in comparison to paper towels especially over the long term. Additionally, the survey showed the public view regarding the impacts of different drying methods varied from the evidence provided in previous studies, particularly in relation to the environmental consequences as many believe the hand dryers are more detrimental ecologically when in reality paper towels have a harsher overall effect.

Key Words: hand dryers, paper towels, public restrooms

Table of Contents

1. Introduction

Humans have created numerous ingenious inventions and machines to simplify daily life, from paper and the printing press to computers. Washing and drying one's hands to sanitize them is one such invention, not nearly as technical as the printing press or computers but used by a vast majority of the world's population on a daily basis. This thesis focuses on the last step of the hygienic process: What is the best or preferred method for drying your hands after sterilization, considering sanitary, environmental, and economic factors? Three common methods of drying include warm air dryers, jet air dryers, and paper towels (Best et al. 2014), with much discussion around which method is more hygienic and efficient. There is also a debate regarding which method is most sustainable and cost effective when comparing the different methods for drying one's hands: Which is less expensive? Which creates fewer net emissions? Does the longer lifespan of an electric hand dryer (Coller et al. 2021) outweigh the monthly purchasing and disposal costs of paper towels in spite of the cost of purchasing an electronic hand dryer?

This thesis will delve into the different methods commonly use for the drying of one's hands, electric hand dryers versus paper towels, to determine the benefits and drawbacks of each in terms of impacts to the environment and cost/benefits from an economic point of view.

2. Objectives

This thesis aims to assess the current usage of paper towels vs electric hand dryers in public restrooms located in the Faculty of Environmental Science buildings, located on the campus of Czech University of Life Sciences. The research hypothesis is that there is a perceived difference as to the environmental and economic impact of both systems by the consumer (students, teachers, and staff). The consumer, in theory, assumes that the presence of state-of-the-art hand dryers (e.g., Dyson) suggests that the business who installs these are promoting environmentally friendly technology and reducing paper waste. However, this theory has not yet been tested to determine if the hypothesis is in fact true, nor is there definitive research to compare the real-world cost/benefit of electric hand dryers vs conventional paper towels.

This thesis will examine prior studies done to determine the sanitary conditions of both hand drying methods, the amount of electricity consumed, and the amount of paper towels used. Also to be explored are the difference in the electric hand dryers, and also the difference in the types of paper towels. This data will be used to determine the more sustainable and economically prudent method for hand drying in public restrooms.

3. Environmental Impact

3.1 Noise Pollution

One of the sub-debates of implementing electric hand dryers into public restrooms, especially those located in vulnerable areas such as hospitals, care centers, etc., is the noise levels of the machines. The World Health Organization did a study in 1999 analyzing the effects of noise pollution, different countries' noise containment policies, and harmful audio levels. The report states that exposure to levels above 85 dB for a long period could cause long-term hearing issues (Berglund et al. 1999). A 2011 study by Shira Daltrop on the noise levels of specifically Dyson Airblades in a university found that the decibel levels the Dyson dryers reached were measured with an average of 84 dB, dangerously close to the maximum according to the WHO research. This indicates that the high-speed variety of electric hand dryers could be harmful to put into public restrooms, especially if the dryers might affect infants and children, the elderly, hearing-aid users, or those with disabilities such as visual impairment. A 2013 study by John Drever in also tested the loudness of the Dyson Airblades in an anechoic chamber, a non-reflective acoustic room where sound can be scientifically tested with high reliability, and again found that the levels recorded were extremely high at about 92-93 dB. The test was re-created in a normal restroom environment and the results rose to about 98-106 dB (Figure 3.1), which the author compared to a "road drill".

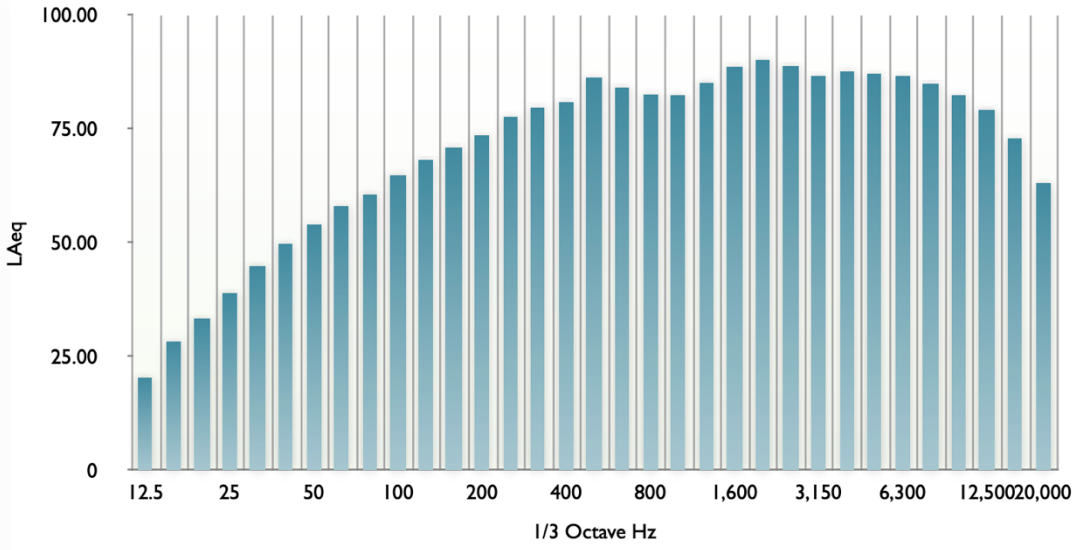

Figure 3.1: Decibel levels of Dyson Airblade dryer in standard restroom environment (Drever 2013)

Noise sensitive groups often avoid bathrooms with electric hand dryers due to the high sound levels (Drever 2013). This issue must be considered when weighing the options of different hand drying methods and whether the noise pollution is high enough to have a considerable enough impact to warrant concern around implementing electric hand dryers.

3.2 Hygiene

In the rivalry between traditional paper towels and new age electric hand dryers, a major battle ensues around their sterility in public bathrooms. Large companies such as Big Towel and Dyson promoting the cleanliness of their products as consumers' perspectives on the sanitary conditions in public bathrooms has a sizeable influence on which of the drying methods they prefer (Marcenac et al. 2021). Numerous studies have been conducted to determine which is the optimal solution when it comes to the bacterial purity with conflicting results.

A key focus on the issue of contamination due to electric hand dryers is the dispersal potential as the worry is that well-cleaned hands become dirty again after drying, with the common assumption being that electric dryers tend to spread bacteria faster and farther due to the fan. A 2018 study conducted at the University of Connecticut School of Medicine tested the presence of specific strains of bacteria both before and after use of electric hand dryers and found the bacteria spread a considerable distance from the source dryers, which the researchers noted could be due to the building's airflow system. However, the spread was determined to be due to the circulation of the air in the room/building and not attributed to internal contamination of the dryers, which was proven with swabs taken of the surfaces of the nozzles and the results did not significantly differ from the specific area's general air. HEPA filters, or "high efficiency particulate air" filters (Figure 3.2), are often applied to electric hand dryers as to help eliminate this spread of bacteria and the researchers tested its viability by applying filters to five dryers and testing before and after filter installation. The average recovered bacterial colonies after installation decreased by four times the amount compared to before the filters were applied, indicating the filters make a substantial difference in the sanitary condition of the air being circulated in and out by the hand dryers (del Carmen Huesca-Espitia et al. 2018). In 2014, another study done

Figure 3.2: Variety of HEPA filters for hand dryers (hygiene-shop.eu)

by Best *et al*. (2014) compared the three main types of drying methods, jet air, warm air, and paper towels, intending to determine the aerosolization and dispersal potential of each. Consequently, the jet air dryer type had the highest bacteria count after close proximity testing, with the warm air dryer being about 4 times cleaner, and paper towels being the most sanitary of the three. Best *et al.* (2014) also conducted a visual test of the droplet dispersal after use of each method, with similar ranking of the different types as the jet air had the widest scattering while the warm air slightly less and the paper towels with little to none (see Figures 3.3, 3.4, 3.5). The authors concluded that considering the potential for scattering of bacteria, the electric hand dryers might have potentially negative effects in high-sensitivity and high-risk environments such as hospitals and healthcare centers and should be excluded in order to decrease chances of contamination via airborne particulates (Best et al. 2014). Another study by Ngeow *et al.* (1989) also investigated the aerosolization capability of paper towels and electric hand dryers and came to the similar conclusion that paper towels had minimal droplet dispersal while the hand dryers demonstrated a concerning

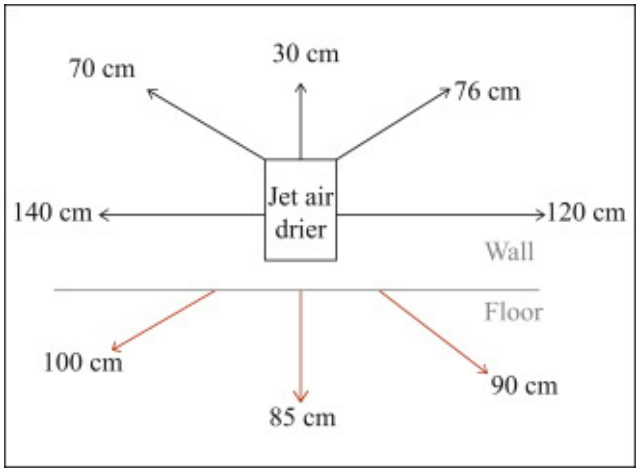

Figure 3.3: Jet dryer droplet dispersal (Best et al. 2014)

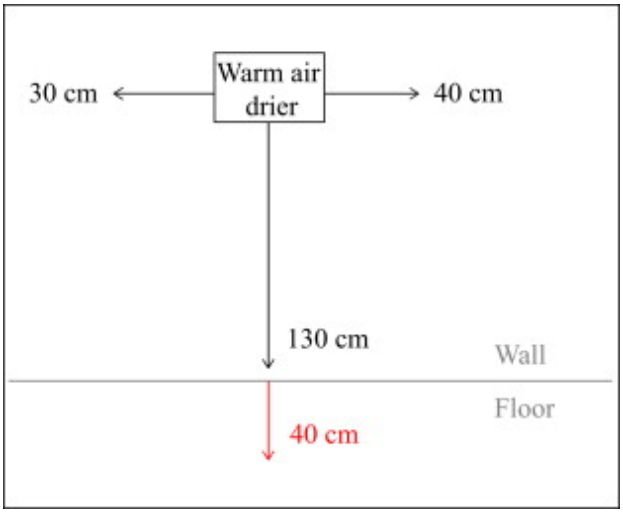

Figure 3.4: Warm air dryer droplet dispersal (Best et al. 2014)

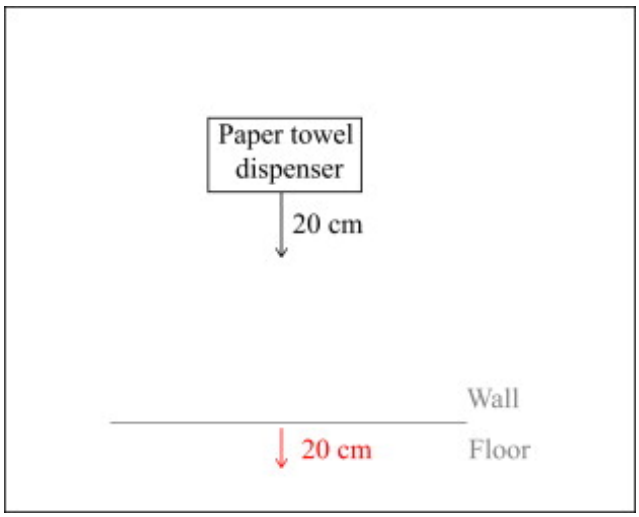

Figure 3.5: Paper towel dispenser droplet dispersal (Best et al. 2014)

level of spray that could suggest they are unfit for sensitive care environments. Matthews and Newsom (1987) ran an experiment testing the bacterial aerosols produced after drying hands with either paper towels or a hot air dryer and found the mean count of bacteria was consistently higher for paper towels than for the electric hand dryers, directly opposing the data found by Ngeow *et al.* (1989). This illustrates the ongoing debate over the hygiene between the different drying methods, although it must be acknowledged that these two studies were carried out in the past and may not be representative of the current situation. Gustafson *et al.* performed a study in 2000 on the effects of four various drying methods (cloth towels, paper towels, warm forced air, and spontaneous room air evaporation) and found no perceivable difference between any of them, contributing another contradictory element to the data pool relating to the salutariness of differing hand drying techniques. Additionally, a 2010 study by Snelling *et al.* directly compared the conventional warm air dryers to the newer jet air dryers, specifically the Dyson Airblade, and discovered that the jet air dryer produced similar bacterial results at 30s of use while at 10s the jet air dryer outperformed the warm air dryer considerably with significantly less transfer of bacteria to the hands. Snelling *et al.* (2010) also determined that the rubbing of hands together as is common with warm air dryers nullifies the bacterial reduction that occurred while handwashing, concluding that the jet air dryer was more effective in terms of hygiene and could incentivize the use of jet air dryers in public restrooms.

3.3 Energy Emissions

Despite efforts to transition to cleaner and more sustainable energy sources, the majority of global energy production still relies on fossil fuels. In 2020, according to Our World in Data, 84% of energy production came from fossil fuels, with 63% of electricity generated from these sources (Ritchie and Roser 2022). This heavy reliance on fossil fuels exacerbates greenhouse gas emissions and other environmental problems.

When it comes to hand dryers, the argument centers mainly around whether the electricity required to power the machines is more or less harmful than the constant purchase and disposal of paper towels, and how much of a factor fossil fuels are. Carvalho and Abrahao (2017) researched this issue at the Federal University of Paraiba in Brazil in order to determine the affect paper towels and electric hand dryers had on the annual carbon dioxide equivalent (kg CO_2-eq) emissions. Their findings broke down the data into sections: waste scenario, transportation, maintenance, operation, and equipment, while also including the different types of paper towels (fresh, 50-50, recovered). Fresh paper towels are made from virgin pulp, recovered towels are manufactured from 100% recycled paper, with 50-50 being a mix of the two. Their results (Figure 3.6) indicated the emissions from paper towels had extremely high CO_2 equivalent emissions especially in the waste, transportation, and operation categories. Although the recycled paper towels did have a decreased effect compared to the virgin towels, the amount still differed drastically from the hand dryers as the dryers had very little emissions, specifically in the transportation area.

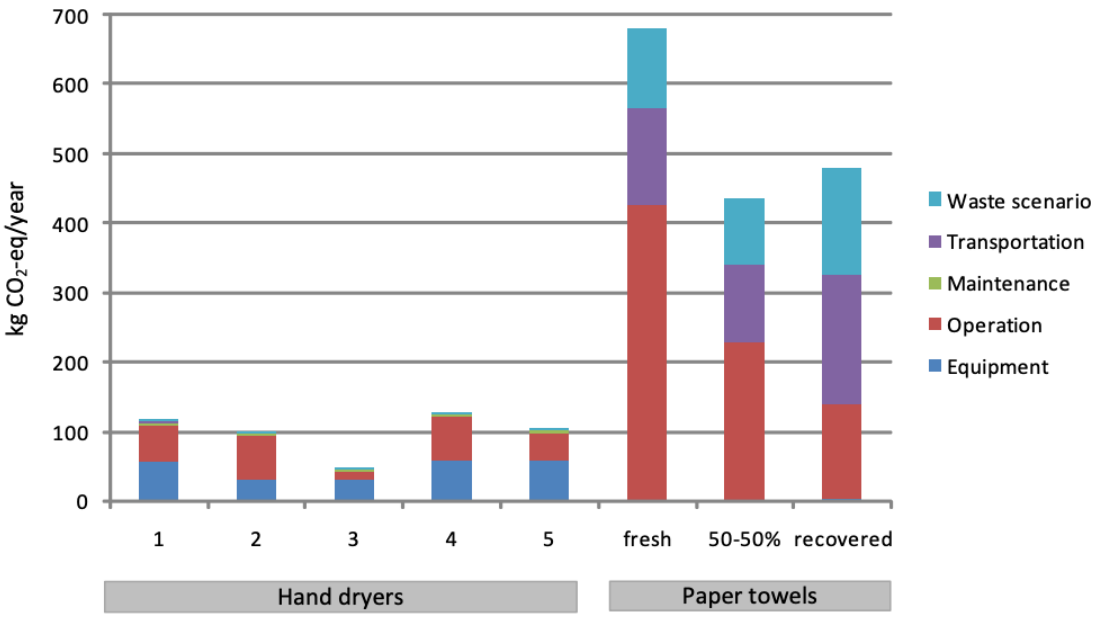

Figure 3.6: Equivalent CO_2 emissions from hand dryers and paper towels (Carvalho and Abrahao 2017)

The authors also ran three simulations of the same situation: the first took into account majority (71%) of Brazil's energy is sourced from hydropower and substituting oil-based sources for 30% of that total; the second simulation substituted coal sources for 100% of the energy production; the third did not alter the electricity source for either drying method but considered if all paper towels were recycled instead of becoming waste. In the first scenario, the totals for the hand dryers did approximately double from the original findings but the emission levels were still considerably lower relative to the paper towels' increase (Figure 3.7). Even with an additional supply of energy originating from fossil fuels and the operational emissions of the paper towels not rising significantly, if at all, the hand dryers continued to outpace the towels. The

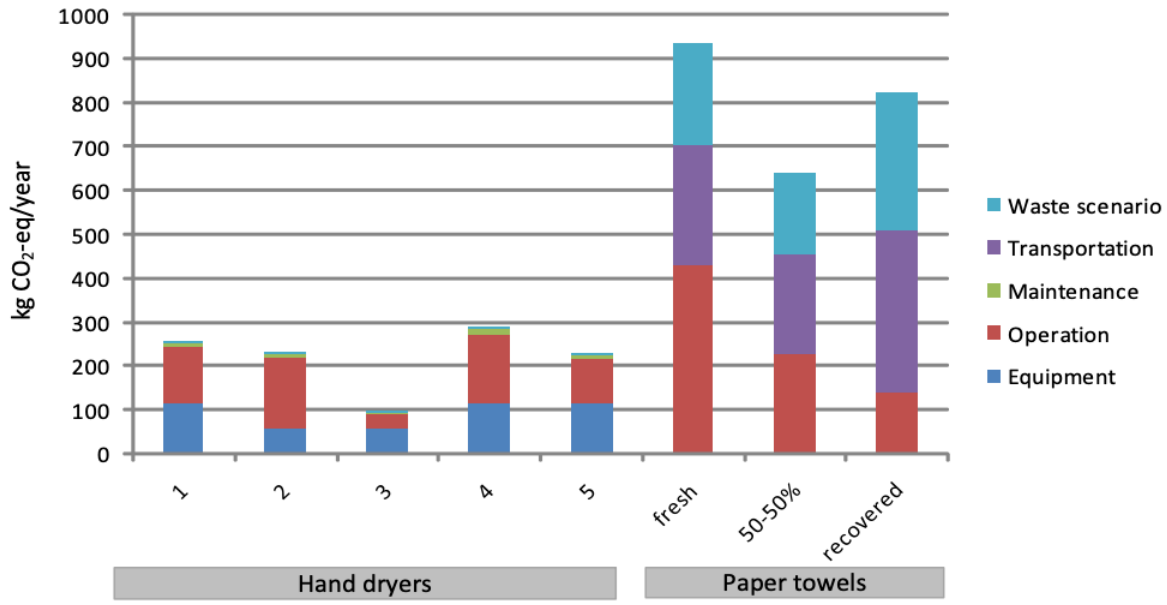

Figure 3.7: First simulated substitution of 30% of hydropower with oil-based electricity (Carvalho and Abrahao 2017)

second scenario produced more elevated results in the emissions of the hand dryers while the paper towels remained similar to the results of the first scenario, indicating the hand dryers did become more environmentally impactful but not enough to begin considering the paper towels, including the recovered type, as reasonable alternatives (Figure 3.8). The third simulation showed that recycling the different types of paper

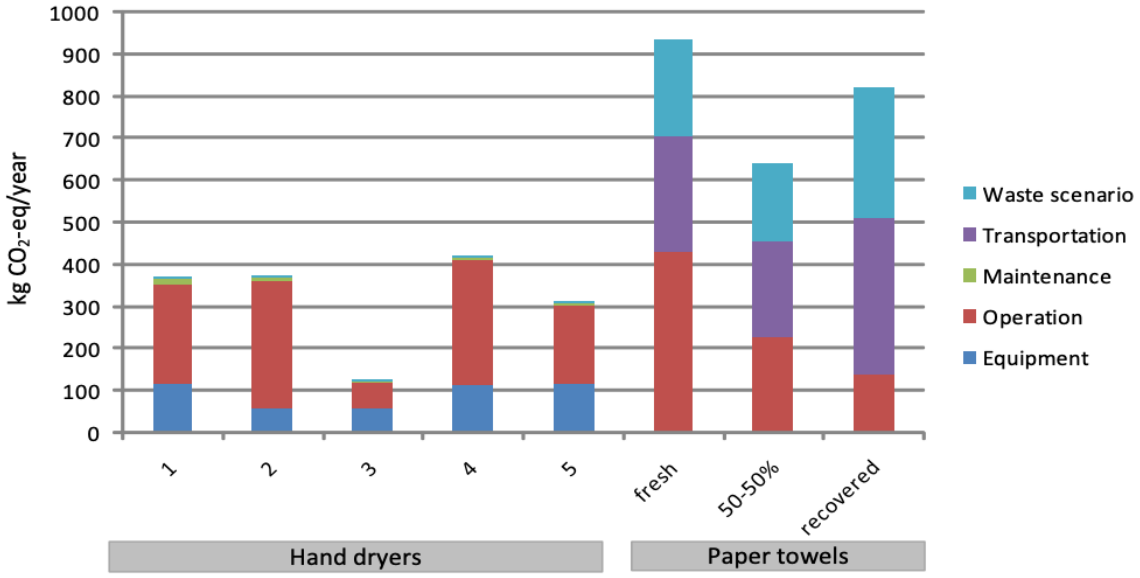

Figure 3.8: Second simulated substitution of 100% electricity as coal-based (Carvalho and Abrahao 2017)

towels would lead to a slight decrease in the contributed annual CO_2-eq emissions and although the recovered towels had a decent emissions offset, the overall result would again not be enough to compete with the low levels the hand dryers produce (Figure 3.9). A 2009 study by Bonatto *et al.* analyzed the differences between high-speed dryers (Dyson Airblade, Mitsubishi Jet Towel), conventional hot-air dryer, and paper towels, finding the Airblade had the lowest emissions at ~70 kg CO_2; next the Jet Towel at 121 kg CO_2; the conventional dryer had ~263 kg CO_2, with the paper towels having the highest at 657 kg CO_2. This further supports the idea of hand dryers being more environmentally prudent with less yearly emissions than the traditional paper towels. A similar 2007 study at the University of Melbourne also examined the

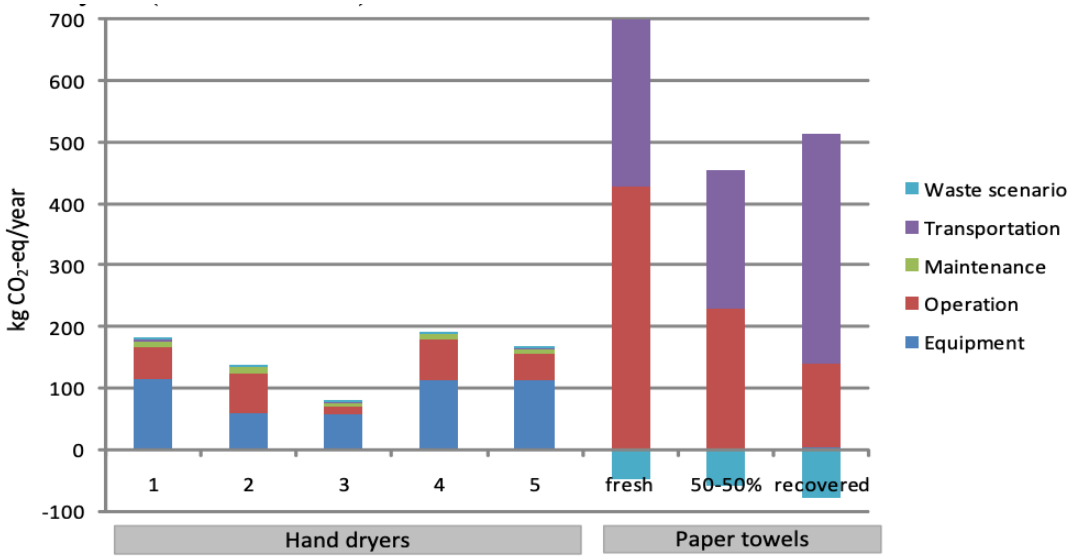

Figure 3.9: Third simulation with 100% recycling of all paper towels (Carvalho and Abrahao 2017)

emissions from both paper towels and hand dryers, finding three different major greenhouse gasses being emitted: carbon dioxide, methane, and nitrogen oxide (Table 3.1). Each type of gas has a global warming potential (GWP) that is the effect each would have as a greenhouse gas with carbon dioxide as the base at 1 GWP, methane at 21 GWP, and nitrogen oxides at 310 GWP (Budisulistiorin 2007). Hand dryers had a much greater amount of carbon dioxide emissions over the entire life cycle and a slightly higher amount of methane emissions, while the paper towels had a much greater amount of the nitrogen oxides released. Overall, the hand dryer had the better

performance over its lifetime when referencing emissions of these three chemicals even when 90% of the electricity supply sources from fossil fuels and only 10% renewables (Budisulistiorin 2007).

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**

Table 3.1: Carbon dioxide, methane, and nitrogen oxides emissions from paper towels and hand dryers (Budisulistiorin 2007)

Excel Dryers, the company behind the XLERATOR dryer, conducted a study in 2009 comparing the equivalent CO_2 emissions from the XLERATOR, a standard dryer, fresh paper towels, and recycled towels (Figure 3.10). Included were different energy sources in the United States intending to show the increase and reduction in emissions based on the energy production method, comprising of the typical grid mix, coal, and wind. The study looked at five life cycle periods: materials production, manufacturing, transportation, use, and end of life. The XLERATOR performed the best no matter which energy source was used, with recycled towels second and standard dryers and virgin towels having a similar effect except for the wind source where standard dryers had a drastic decrease in emissions (Dettling and Margni 2009). Majority of the results for the two dryers were produced during use and if the electricity provided to power the hand dryers during use derived from a renewable process, the climate change score as given by Dettling and Margni (2009) would be drastically decreased. Additionally, the paper towels' majorities were produced during the manufacturing stage, with all methods having noticeably lower results in the wind category indicating once again that if a renewable energy source is implemented, then the climate change impact is lessened considerably. These results are further supported by the work of Coller *et al.* (2021) which concluded that hand dryers have a lesser emission extent as compared to paper towels and even more so if alternative, or renewable, energy sources are applied to the hand dryers, although the authors state that this only pertains to situations with

greater than 5 uses per day otherwise the energy constantly being pulled by the hand dryers when not in use overcomes the previously stated advantage.

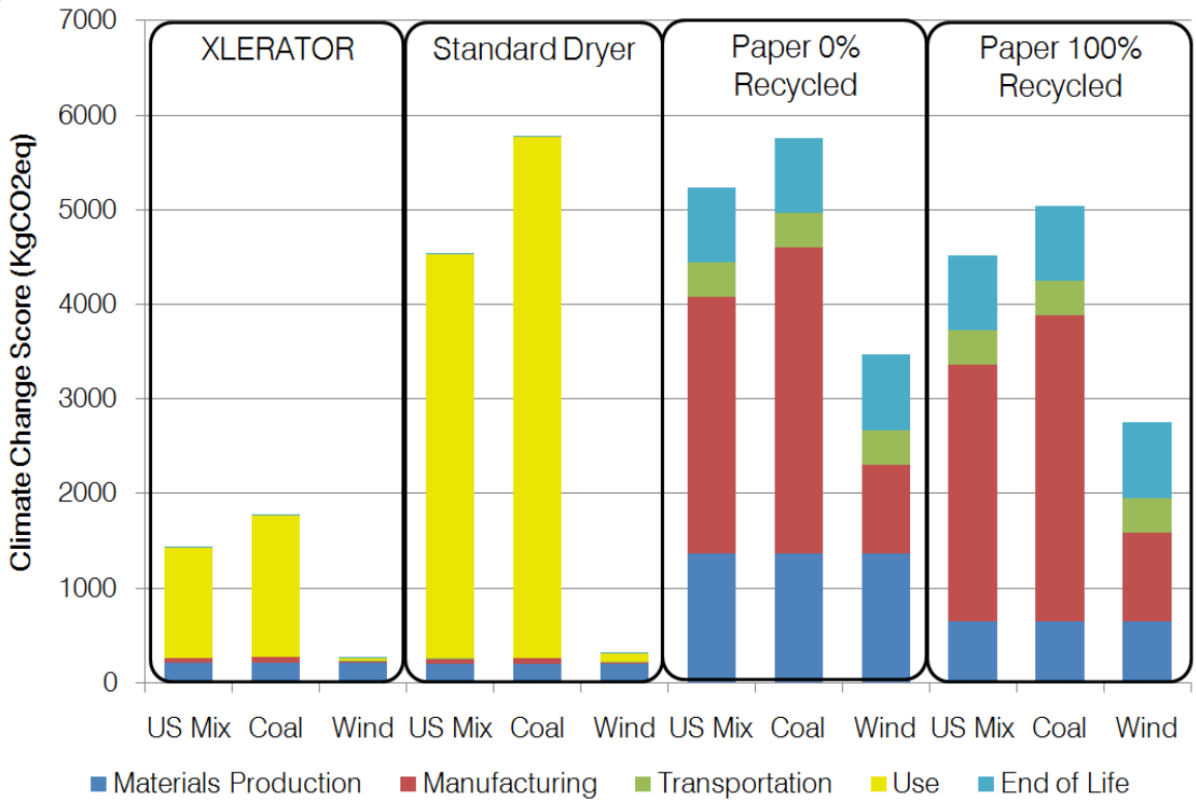

Figure 3.10: Excel Dryers study on emission impact of different hand drying methods (Dettling and Margni 2009)

A 2013 study by Gregory *et al.* investigated the environmental impact of five different drying methods over their life cycle from cradle to grave or beginning of production to waste disposal: hands under (HU), high-speed hands under (HSHU), high-speed hands in (HSHI), cotton roll towels, and paper towels. The data was measured in three separate ways, starting with the measured drying times, then the manufacturer-reported drying time, and the reported drying time plus a printed wiring board (PWB) which is a key building block in electronics and could affect the drying times of each dryer. In Figure 3.11, the results for each data gathering type can be seen to be similar with HSHI dryers at the lowest GWP while HU dryers had the highest GWP (Gregory et al. 2013). Majority of the GWP produced by the hand dryers and the cotton roll towels

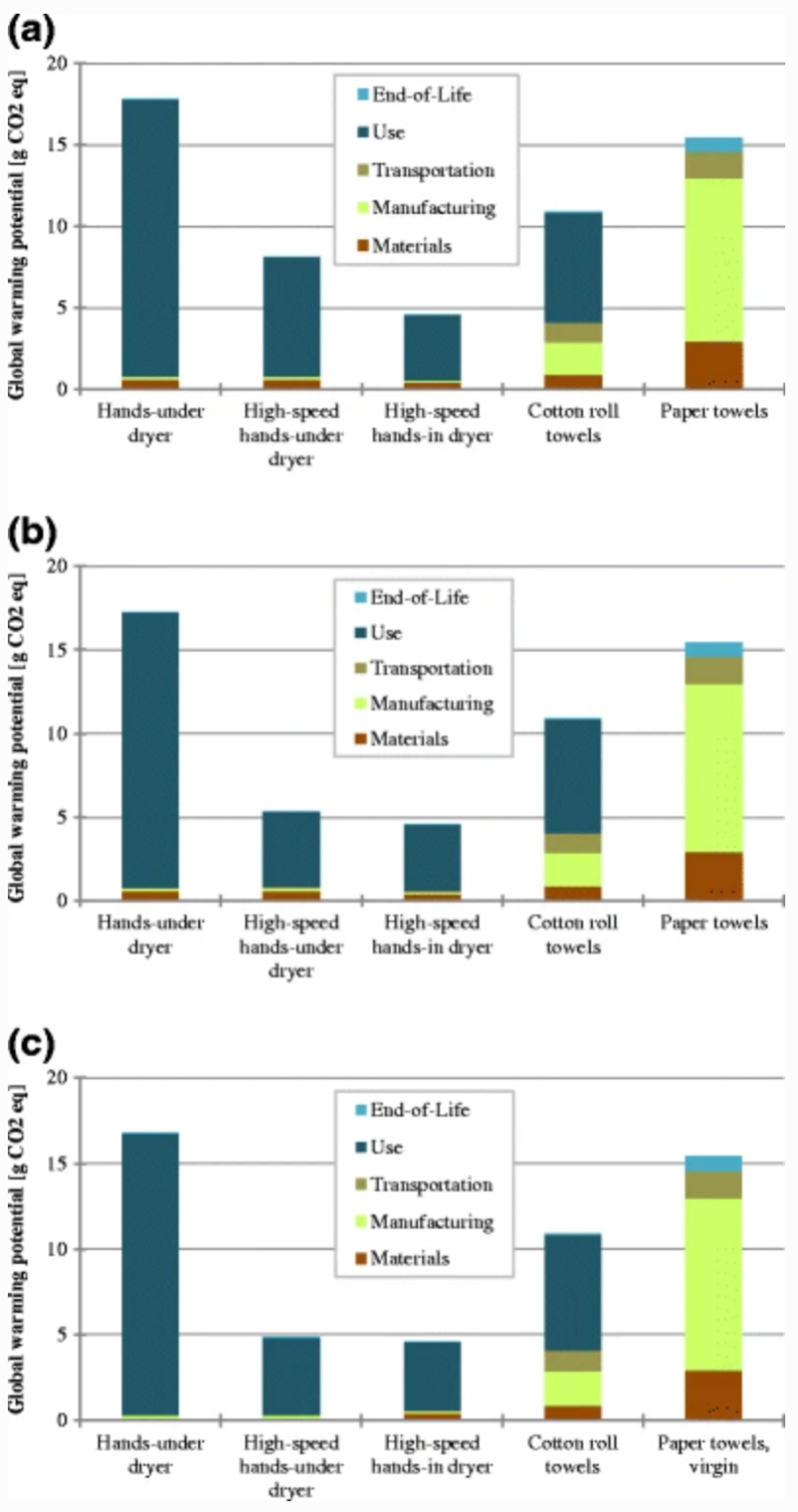

Figure 3.11: Global warming potential of 5 different drying methods in three separate data measuring scenarios (Gregory et al. 2013)

again originated during use, while the paper towels' majority originated during manufacturing (Gregory et al. 2013). Joseph *et al.* (2015) conducted a similar study analyzing the emissions from cradle to gate, or beginning of production to use, instead focusing on conventional hot-air dryers and paper towels instead of the high-speed dryers and cotton roll towels. The results as seen in Figure 3.12 were analogous to Gregory *et al.* (2013) in that the conventional dryer had less than half the emissions that the paper towels did, with majority of the dryer emissions again produced during use and majority of the paper towel emissions also produced during use, most likely due to the production and transport of the paper towel rolls being grouped in this category (Joseph et al. 2015). The energy supplied to the dryers is sourced from nuclear and natural gas, leaving room for additional renewable energy to replace the fossil fuels.

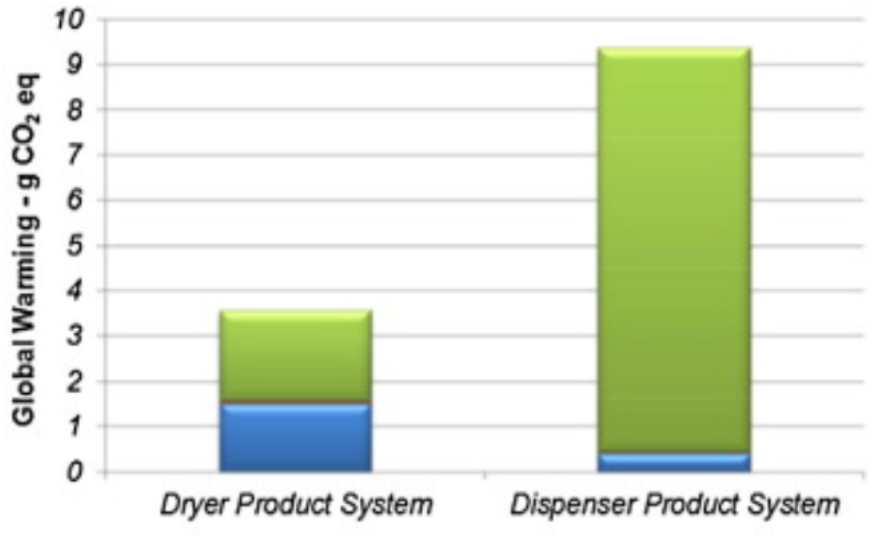

Figure 3.12: Global warming potential of conventional dryer vs. paper towels (Joseph et al. 2015)

3.4 Sustainability

While concerns about harmful emissions from both paper towels and hand dryers have been the focus of studies, other aspects of their life cycle could also have significant sustainability implications, from land use to resource consumption to impacts on human health. These impacts should also be taken into consideration when weighing between the two drying methods.

The previously mentioned study by Budisulistiorin (2007) also analyzed the life cycle impacts of paper towels and hand dryers in eleven further categories: carcinogens, ecotoxicity, land use, etc. (Table 3.2). Of the eleven categories, three had no results, and from the remaining eight the paper towels were largely higher in the acidification/eutrophication and fossil fuels sections while the hand dryer had significantly higher results in the land use and minerals categories. According to Budisulistiorin, hand dryer components create a need for more land for mining, outweighing the land needed to grow trees for paper production. On the other hand, the process for treating the paper and waste disposal leads to significantly higher air and water pollution as opposed to the hand dryer (Budisulistiorin 2007). The other three impacts (carcinogens, respiratory inorganics, and climate change) were of very low values with little difference between the two drying methods. The importance of

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

Table 3.2: Various categories of effects due to paper towel and electric hand dryer use (Budisulistiorin 2007)

these findings is the ignition of the question of whether the more elevated fossil fuels and acidification impacts by the paper towels is better or worse compared to the greater values produced by the hand dryers in land use and minerals impacts. Is the land usage and mining for electrical components in hand dryers worse for the environment, or does the production, transportation, and waste disposal of paper towels have a superiorly negative influence?

Joseph *et al.* (2015) additionally completed comparisons of paper towel dispenser systems' versus hand dryers' impacts on ecosystem quality, resources depletion, and human health. Ecosystem quality was measured in potentially disappeared fraction of species per square centimeter per year (PDF/cm^2/year), indicating how the drying method might affect the flora and fauna in areas of production and use. Resources depletion was measured in kilojoules primary (kJ Primary) illustrating the uptake of resources, especially energy. Human health was measured in disability adjusted life years (DALYs), quantifying the lost years of human life due to each drying method over its lifetime. Similar to the prior results by Joseph *et al.* (2015) in the global warming category, the paper towels outperformed the hand dryers in both human health and ecosystem quality, although the towels did have lower results than the hand dryers in terms of resource use (Figures 3.13, 3.14). Nearly the complete impact of the dryer system in the resource category was during the use phase as the primary necessity

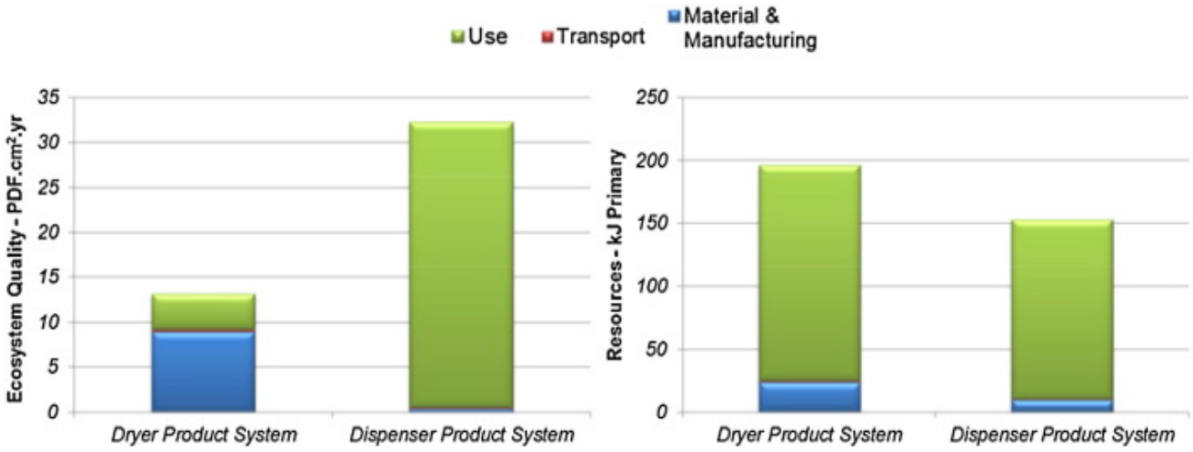

Figure 3.13: Ecosystem quality and resource depletion due to paper towels and hand dryers (Joseph et al. 2015)

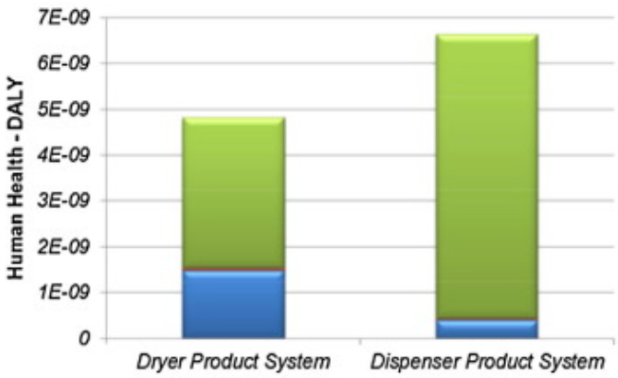

Figure 3.14: Human health impact comparison between hand dryers and paper towels (Joseph et al. 2015)

for electric hand dryers is the electricity needed to run the machines, and the authors did note that 85% of the dryer impact in the resource category was due to nuclear and natural gas sources (Joseph et al. 2015). Both methods had majority of their results in each category occur in the use phase, although the hand dryers had a majority occur in the materials and manufacturing phase for ecosystem quality, most likely due to mining efforts and land use as mentioned before. Another important observation is that this study did not take into account the waste and disposal costs which could alter the results, although unlikely when compared to previous studies' outcomes.

3.5 Waste

An important factor in the life cycle analysis of both paper towels and hand dryers is the waste scenario. The method of disposal can make a difference in the impact on the environment and lead to less pollution and more recovered resources. The most common disposal procedures are recycling and composting for the paper towels, and possible rare-earth elements (REEs) and waste electrical and electronic equipment (WEEE) that can be recovered from the electronic waste of the hand dryers. The question becomes: Which methods are viable solutions, and which are considered to have an overall negative affect?

3.5.1 Recycling and Composting

A common discussion around paper waste is whether recycling is an option, and if not, then what other options there are, with composting being one of the main alternatives to landfilling. A 2012 study by Brennek *et al.* included an impact assessment of recycling and composting, analyzing the manufacturing stage, the transportation stage, the use stage, and the disposal process for each method. The compost process additionally had an "avoided burden" due to the natural fertilizer that is produced and could replace the artificial fertilizer (Brennek et al. 2012). As can be seen in Table 3.3, the compost method had a lower impact in all categories except solid waste and electricity use. When the avoided burden is compiled with the original impacts, the results for the composting method decrease across all areas except for electricity usage which again is not affected. Notably, recycling had a definitively higher score in the climate change category likely due to emissions during transportation by rail (Table 3.4). Additionally, the emissions during composting are relatively decreased due to the transformation of the carbon in the compost pile to carbon dioxide instead of methane as the airflow being pulled through the material oxygenates the carbon (Brennek et al. 2012). These results indicate composting as the most viable option for end-of-life paper towel disposal, and recycling as a secondary option as opposed to landfilling, although there are some worries concerning the hygiene of recycled paper towels as they have been found to harbor bacteria (Gendron et al. 2011).

Impact Category	Unit	Recycling Impact	Compost Impact without Avoided Burdens	Compost Impact Characterization with Avoided Burdens
Climate change	kg CO2 eq	1039.3	873.5	734
Human toxicity	kg 1,4-DB eq	38.8	36.8	29.8
Water depletion	m3	24.7	24.6	23.4
Fossil fuel depletion	kg oil eq	385.8	328	308
Solid waste	Kg	62.8	75.6	66.8
Electricity Use	kWh	32.4	32.4	32.4

Table 3.3: Impact assessment of disposal methods for paper towels (Brennek et al. 2012)

Input	Recycling	Composting	Unit
Waste paper, sorted	1,013	1,013	kg
Water, natural origin	23.5	23.5	m3
Electricity	62.8	82.8	kWh
Natural gas	8,710	8,710	MJ
Transport, rail	8,886	4,443	t-km
Transport, lorry	47	37	t-km
Corrugated board	23	23	kg
Machine diesel for process	0	2.27	L

Table 3.4: Life cycle impacts of recycling and compost across a variety of categories (Brennek et al. 2012)

Venelampi *et al.* conducted a study in 2013 to determine the biodegradation of paper products with varying compositions in a compost environment. The study included hand towels constructed from bleached pulp (TC2), recycled fibers (TR2), and recycled fibers combined with mechanical pulp (TRM2). Bleached products contain chemicals in order to change the color, particularly to white in most cases for paper production, and remove lignin which will turn the pulp both yellow and brittle over time (Mleziva and Wang 2012). Mechanical pulp is made through physical means, typically by thermal addition or by grinding, and leads to higher pulp production but also higher lignin content (Mleziva and Wang 2012). Venelampi *et al.* (2013) inserted each type of paper product into 4.5-month-old compost as that is the most optimal timeframe with a cellulose-based sausage casing as reference. The bleached pulp had the quickest degradation with nearly 100% before day 50, while the recycled fibers and combination products were similar to each other with > 90% degradation before day 75 (Figure 3.15). This heavily contrasts plastics which typically degrade over decades or centuries (Chamas et al. 2020).

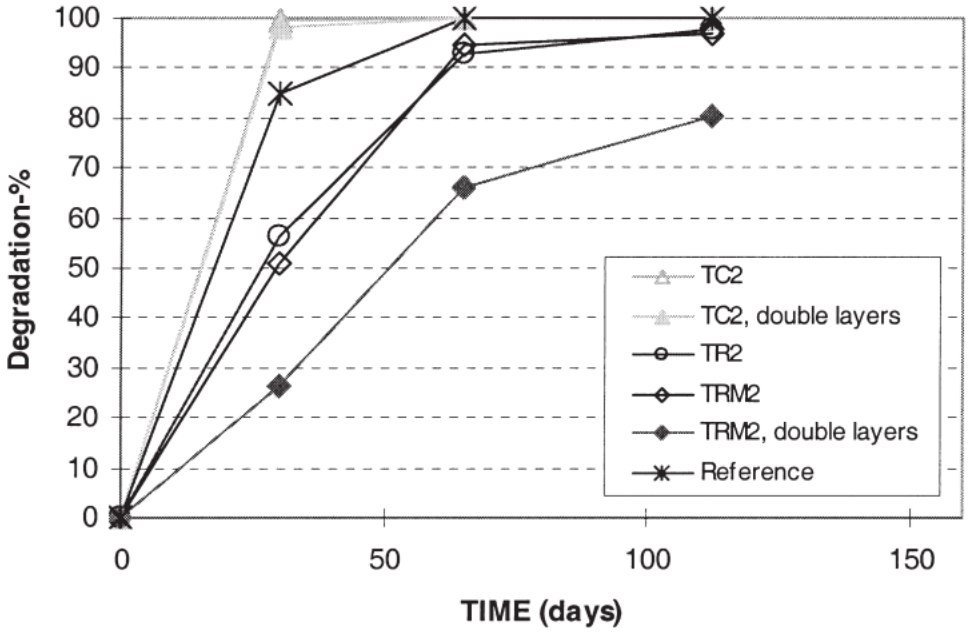

Figure 3.15: Degradation rates of various paper compositions inserted in compost piles at 4.5 months (Venelampi et al. 2013)

3.5.2 WEEE and REE Recovery

Electronic waste has seen massive growth as the world moves towards an increasingly digital age, with 53.6 million metric tons (Mt) of e-waste generated in 2019 and rising at a rate of 2Mt per year, with expectations to reach 74Mt in 2030 (Forti et al. 2020). As end-of-life hand dryers are included in this e-waste, the retrieval of any reusable portions of the machines could have a positive impact on the environment. The issue with recycling e-waste lies in the complexity of the design of many technologies and calls for separate techniques to recover valuable reusable materials as well as remove any components that could potentially be harmful to humans or the environment (Tanskanen 2013). Unfortunately, many common practices for the recycling of waste electrical and electronic equipment (WEEE) involve pit burning and the use of toxic chemicals to separate out valuable parts of the waste and leave the remaining portions, often causing leaching and other environmental issues (Hsu et al. 2019). Alternative processes for removal and separation include disassembly, density separation, magnetic separation, pyrolysis, pyrometallurgy, hydrometallurgy, and biometallurgy, although the sustainability and efficiency of these methods needs further study (Hsu et al. 2019). As WEEE is constructed from printed circuit boards (PCBs) and the casing,

which is typically plastic or metal covering the PCB, Debnath *et al.* (2016) suggests that the electronic components (ECs) inside of the WEEE be separated out by the type of ECs they contain: either versatile and widely used components that could be recycled back into further electronics or specific ECs that are intended for particular products. The idea behind this is to narrow down the types of WEEE to those that have more EC content and those that have more plastic/metal casing content, such as a television having higher EC content than a keyboard with a majority of plastic in the casing (Debnath et al. 2016). This methodology could increase recyclability of e-waste, but the sustainability again needs to be further researched and documented.

Along with e-waste is a similar issue of recovery of rare-earth elements (REEs), materials that have grown in demand in recent years with the rise in electronic devices production (Rene et al. 2021). These include scandium, yttrium, and the fifteen lanthanides ranging from atomic numbers 57-71 (Qu and Lian 2013). Several methods have been devised to recover these elements, such as acid dissolution, liquid media extraction, direct melting, etc., but often come with high costs, pollution and sludge, and the resulting recovered product is low grade (Reed et al. 2016, Sethurajan et al. 2019). An emerging technique for recovery that involves lower costs, higher efficiency and more sustainable operations is bioleaching. Bioleaching incorporates the use of microorganisms to extract the 17 REEs from waste materials such as the previously mentioned e-waste (Dev et al. 2020). As with the WEEE recycle methods discussed above, bioleaching has potential to be a viable alternative to current recovery techniques (Dev et al. 2020) and could be applied to the hand dryer disposal process in order to avoid additional environmental pollution and damage and to recycle valuable electronic components.

4. Economic Impacts

Alongside the environmental impacts come the economic implications of varying hand drying methods and as the world moves towards a more sustainable global market, the costs of these more environmentally friendly products play a key part in the transition. Although electric hand dryers have a considerably higher initial price tag (Bonatto et al. 2009), does the constant purchase of paper towels become more expensive than powering the machines?

The previously mentioned 2017 study by Carvalho and Abrahao additionally included an economic analysis of the initial scenario with the 5 electric hand dryers and the three types of paper towels: fresh, 50%-50%, and fully recycled. Their analysis covers both the initial costs of purchasing, shipping, and installment, as well as the operation costs (Figure 4.1). The results show an astounding difference between the two methods with the hand dryers having a majority that are cheaper than the paper towels, excluding the third dryer as it was more expensive initially due to higher purchasing and shipping

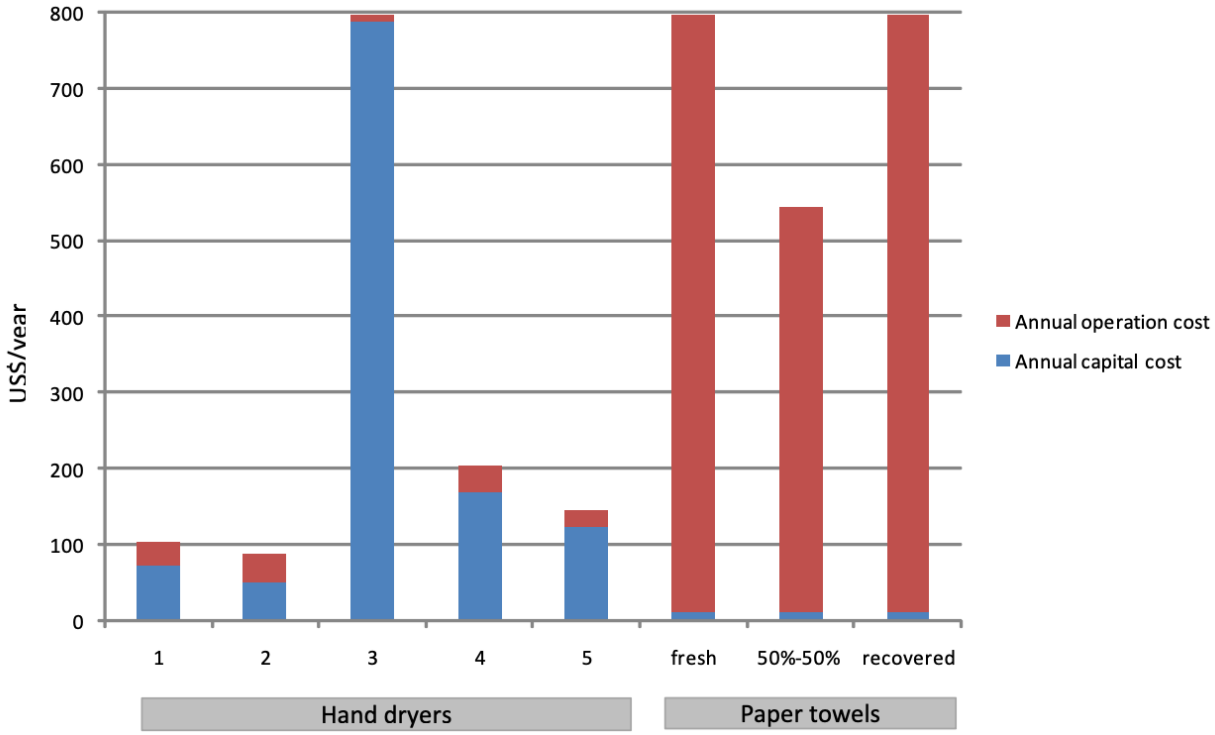

Figure 4.1: Estimated costs of hand dryers vs. paper towels including initial costs and operational costs (Carvalho and Abrahao 2017)

costs (Carvalho and Abrahao 2017). Also important to note is the drastic difference between the paper towels operational costs and the hand dryers capital, or initial, costs; this is due to the heftier price tag of the electric hand dryers and the shipping costs along with installation, while the paper towels are less expensive on the front end but the purchase and disposal costs over the period of approximately 125.5 days (31,375 drying operations with 250 users per weekday) contribute to nearly all of the lifetime economic impact (Carvalho and Abrahao 2017). As mentioned before, the electricity provided in the study primarily came from renewable sources and therefore likely had a positive effect on the overall operational costs of the electric hand dryers, and in other scenarios with predominately fossil fuel use the operational cost could be much higher. Another potential key factor in these calculations is the quantity of uses of the hand dryers per day; the study by Carvalho and Abrahao (2017) kept a constant estimate of 250 uses per weekday, while a similar 2019 study by Schiavon *et al.* incorporated a variable number of daily uses ranging from 10 to 200 (Table 4.1). The results include

	Annual cost of paper towels [€]				Annual cost of a hand drier [€]			
N	minimum	mean	modal	maximum	minimum	mean	modal	maximum
10	20.46	40.47	42.00	64.16	115.55	136.67	134.11	168.04
20	40.93	80.94	84.01	128.31	118.16	139.85	137.19	171.79
30	61.39	121.41	126.01	192.47	120.77	143.04	140.28	175.53
40	81.86	161.88	168.01	256.63	123.38	146.23	143.37	179.27
50	102.32	202.36	210.02	320.79	125.99	149.42	146.45	183.02
60	122.79	242.83	252.02	384.94	128.60	152.61	149.54	186.76
70	143.25	283.30	294.02	449.10	131.21	155.80	152.62	190.51
80	163.72	323.77	336.03	513.26	133.82	158.99	155.71	194.25
90	184.18	364.24	378.03	577.42	136.44	162.18	158.79	198.00
100	204.65	404.71	420.03	641.57	139.05	165.36	161.88	201.74
110	225.11	445.18	462.04	705.73	141.66	168.55	164.96	205.49
120	245.58	485.65	504.04	769.89	144.27	171.74	168.05	209.23
130	266.04	526.12	546.04	834.04	146.88	174.93	171.13	212.98
140	286.51	566.60	588.05	898.20	149.49	178.12	174.22	216.72
150	306.97	607.07	630.05	962.36	152.10	181.31	177.30	220.47
160	327.43	647.54	672.05	1,026.52	154.71	184.50	180.39	224.21
170	347.90	688.01	714.06	1,090.67	157.32	187.68	183.47	227.96
180	368.36	728.48	756.06	1,154.83	159.93	190.87	186.56	231.70
190	388.83	768.95	798.06	1,218.99	162.54	194.06	189.64	235.45
200	409.29	809.42	840.07	1,283.14	165.16	197.25	192.73	239.19

Table 4.1: Annual costs of paper towels and airblade dryers based on number of daily uses N (Schiavon et al. 2019)

the purchase and operational costs for the hand dryers, and for the paper towels the initial installment costs and subsequent supplies purchasing, transportation, and waste disposal were considered. The table clearly shows as the number of daily uses increases from 10, the cost of the paper towels grows from a mean of 40.47 euros to more than 800 euros. On the other hand, the airblade-type hand dryer begins at a higher mean cost of 136.67 euros but as the number of uses increased to 200 the cost was 197.25 euros, only a ~144% growth in comparison to the paper towels' 2000%; this equates to the hand dryer costing ~75% cheaper than the paper towels at 200 daily uses (Schiavon et al. 2019). Coller *et al.* (2021) found a similar positive trend with an increased number of uses resulting in less cost, especially for the hand dryers which had a very low growth (Figure 4.2). The difference found between the two in this study was ~400

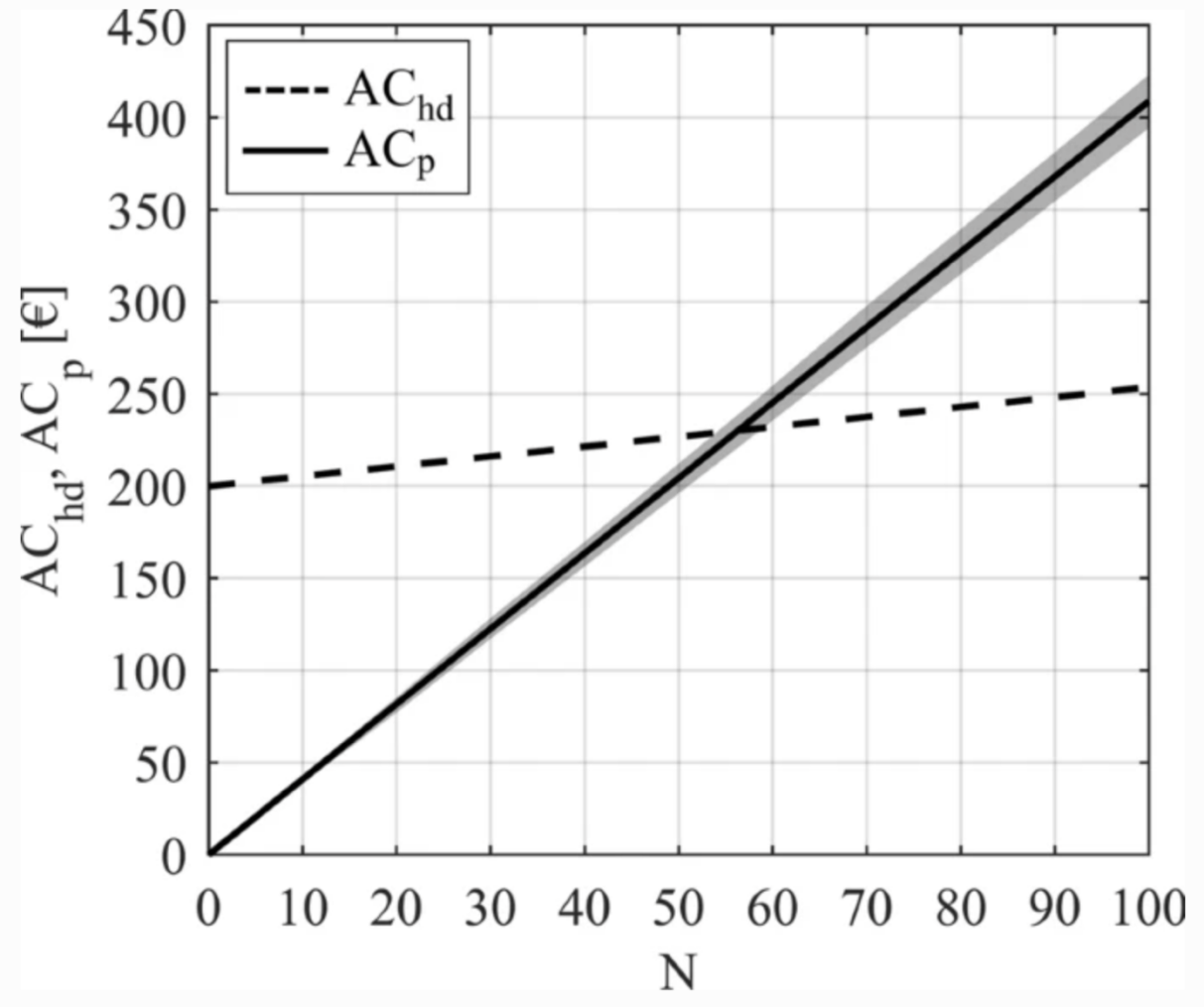

Figure 4.2: Comparison between paper towel cost and hand dryer cost as a function of number of uses N (Coller et al. 2021)

euros for the paper towels (solid line) as opposed to 250 euros for the hand dryers (dashed line) at 100 uses. In this instance, the hand dryer is ~37% cheaper than the paper towels (Coller et al. 2021).

A 2009 study by Liew *et al.* analyzed different hand drying options on the campus of the University of British Columbia: paper towels, cloth towels, and hand dryers (Dyson Airblade). The different choices were evaluated based on purchasing price, transportation, maintenance, and disposal/recycle; additionally, the cost for washing and drying of the cloth towels was included in the final analysis (Liew et al. 2009). The authors also considered the implementation for the entire building and multiplied the cost for a single unit by 50 and extrapolated the annual data up until the 15-year mark (Table 4.2). As seen, the cloth towels had the cheapest first year and 15-year

Hand drying method	**Cost of acquiring 50 new unit**	**Cost of maintenance($)**	**1st 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

Table 4.2: Financial analysis for 50 units of various hand drying options over a 15-year period (Liew et al. 2009)

estimates, while the hand dryers were the most expensive the first year but were outpaced by the paper towels by the end of the 15-year period. The cloth towel is consistently the cheapest option even when the cost of washing and drying is incorporated in the calculations, concluding at the 15-year point at half the price of the next option, the electric hand dryer. The initial purchase price of the hand dryers clearly has a considerable impact on its final costs but when the longer lifespan is accounted for by extending the timeframe the relatively low maintenance and use costs decrease the long-term cost. On the other hand, the paper towels have a lower purchase price, although the transportation and disposal costs are higher, but the constant maintenance and restocking increased the final price by a sizable amount to make the paper towels the most expensive option. This is supported by a similar study by Adeeb *et al.* (2009) analyzing the costs of implementing recycled paper towels and several types of electric

hand dryers: the Mitsubishi Jet Towel, Dyson Airblade, and Excel Xlerator. The initial purchasing price, use/restock costs, and recycle costs were included in the estimation. The authors likewise extrapolated the annual data to estimate the 15-year price point for each drying type (Table 4.3). The Xlerator had the cheapest initial and operational costs, while the Airblade was the most expensive electric hand dryer even when considering a longer timeframe of 15 years. Although the recycled paper towels were nearly tied for the cheapest option after initial costs, the yearly operating costs were by far the most expensive and after the 15-year period were 16 times more expensive than the next option (Airblade). These results were for single units and if applied to numerous set ups the difference in final cost estimates would be greater (Adeeb et al. 2009). This again shows the paper towels are more costly over a longer period of time

Type	Initial Cost	Yearly Operating Cost	Total Cost After 15 Years
Mitsubishi Jet Towel	$1680	$6.74	$1881.10
Dyson Airblade	$1790.88	$26.38	$2286.70
Excel XLerator	$500	$21.33	$919.95
Recycled Paper Towels	$502	$2498	$37970

Table 4.3: Financial analysis over 15-year period for several electric hand drying methods and recycled paper towels (Adeeb et al. 2009)

than the electric hand dryers, including the relatively cheaper option of recycled paper towels (Liew et al. 2009). Cai *et al.* (2009) came to a similar conclusion with paper towels having a cheaper initial price but much higher cost over a 15-year period of time. Additionally, out of the three types of electric hand dryers tested (GXT Extreme Air, Mitsubishi Jet Towel, and Dyson Airblade) the GXT was the cheapest option both initially and long-term, with the Airblade being the most expensive at first but beating the Jet Towel in the long-term, contrasting the results found by Adeeb *et al.* (2009) (Cai et al. 2009).

5. Methodology

This Bachelor Thesis encompasses two different sources of data to obtain an analysis of the study from two different viewpoints: an in-depth literature review on particular subjects related to both hand dryers and paper towels, and a public survey implemented in university restrooms.

5.1. Literature Review

The background knowledge on this subject is of vital importance for this thesis, thus is the role of the literature research conducted in parts 3. and 4. Capitalizing on the massive information capacity of the internet, Google Scholar was primarily utilized to search for articles on the topics related to paper towels versus hand dryers debate due to the search engine's credibility and specificity in its results. Initially, the abstract of the articles would be scanned for relevant information that could contribute to this thesis, and if so, would be sorted into the different sections as previously seen: "Environmental Impacts" and "Economic Impacts". These articles included textbook additions, pieces from medical journals, and so on. After organizing the articles, the structure and flow of the chapter would be determined by the order of the articles and the connection between each. If additional information was needed, Google Scholar was further consulted. Each and every article was then cited, and all authors credited as to avoid plagiarism.

5.2. Survey

The survey portion is key to understanding the perspective, and subsequently the possibility of changing the habits, of the public in terms of the preferred drying methods and why. This also allows for a more complete picture of whether different drying techniques are effective or if the use of said techniques is incorrect. The university was chosen due to the presence of both electric hand dryers and paper towels, and because of the wide diversity in people, profession, and age.

The first option for setting up the survey originally was "Google Survey" due to the easy access through Office 365 and easy set up, but the service was to be taken down before the survey could be implemented. Subsequent solutions included "Survey Monkey", "Survey Planet", and various other free survey-hosting sites. Ultimately,

"HostGator", a web hosting site, was used to purchase the domain name while "WordPress" was utilized to set up the website's pages and forms. The website was created to host a survey that can be accessed by users via a QR code posted in restrooms in the D and Z buildings inside the FES faculty on CULS campus. A landing page was created with a QR code linked to that specific page in order to direct those who scanned the QR code to the two different survey form choices, either in the native language of Czech or English. The survey only appears if the code is scanned so as to reduce any chance of incorrect data being entered. The QR code was then put on a page with two sets of text, again Czech and English (Figure 5.1). The text reads as follows:

Which is more sustainable: Hand Dryers or Paper Towels?
Please scan this QR code to take part in a survey to answer the question above as a vital portion of a 3rd year Bachelor of Environmental Engineering student's thesis comparing the environmental and economic impacts of each hand drying method in FES's restrooms. Thank you for the help!

The Czech text is a translated duplicate.

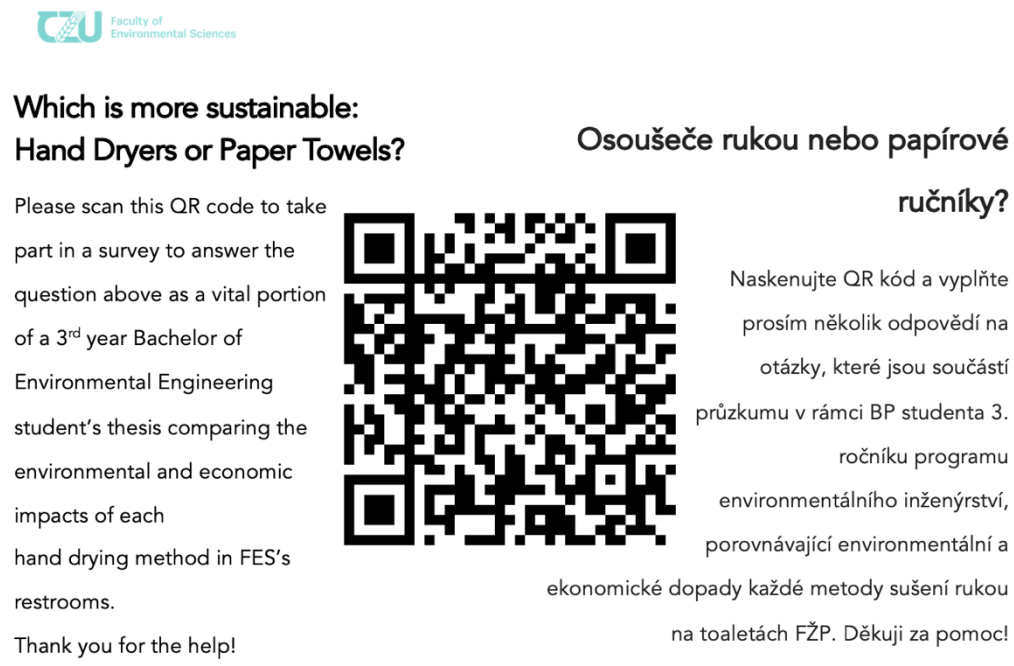

Figure 5.1: Posted survey form including both Czech and English text (Source: author)

The QR code posters were taped up across a total of 34 restrooms in the two buildings, 15 in Z and 19 in D. The full list of restrooms can be found in the Appendix, along with the entirety of both versions of the survey. All questions in the survey required an answer to submit, except for the why portions of the two extended answer questions.

6. Results

The following results are summarized from the responses to the QR code mentioned above.

The QR codes were posted in the restrooms on January 12th, 2023, and final results were taken on February 10th, 2023. Overall, 85 responses were received with 60 being in the Czech language and 20 in English. As seen in the figures below, majority of the participants were of Czech nationality, more than twice the amount of international surveyees. Approximately half, or 44 of the respondents, selected Female while about

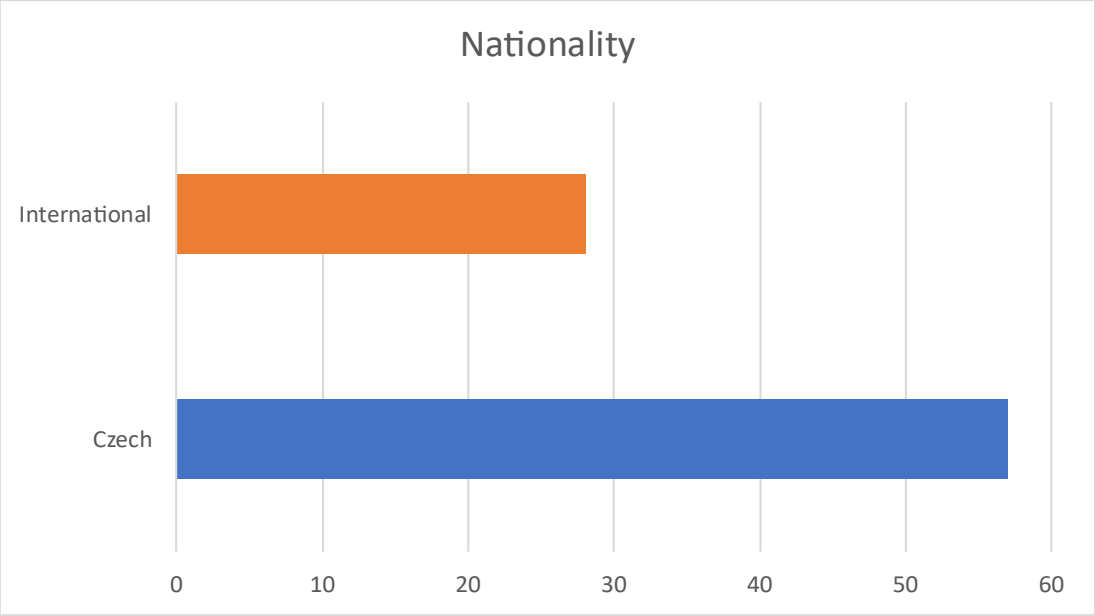

Figure 6.1: Nationality of participants in survey (Source: author)

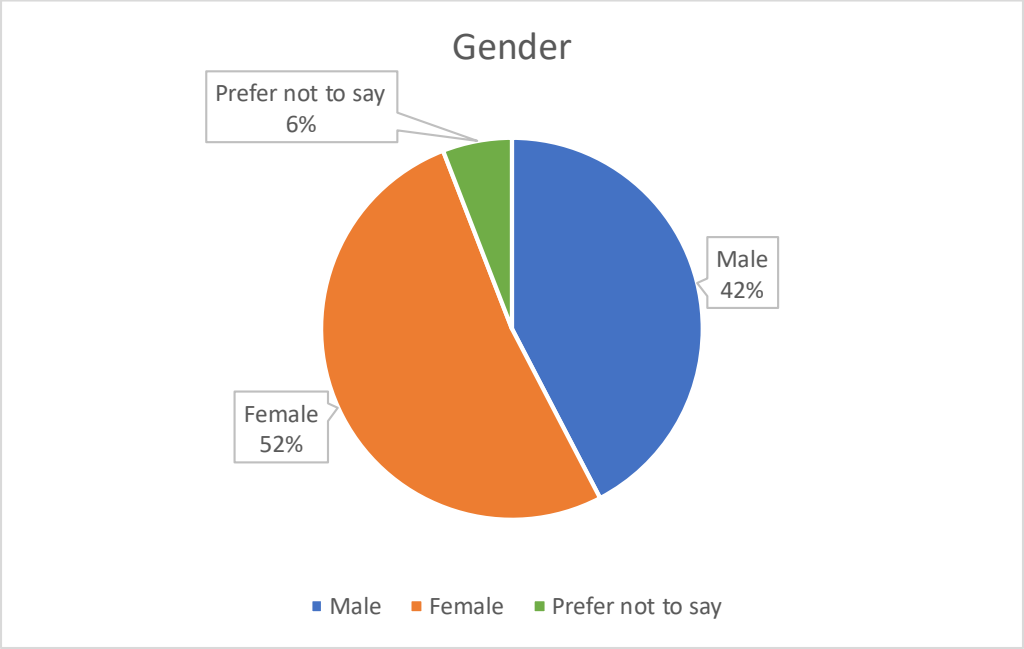

Figure 6.2: Gender preference of participants (Source: author)

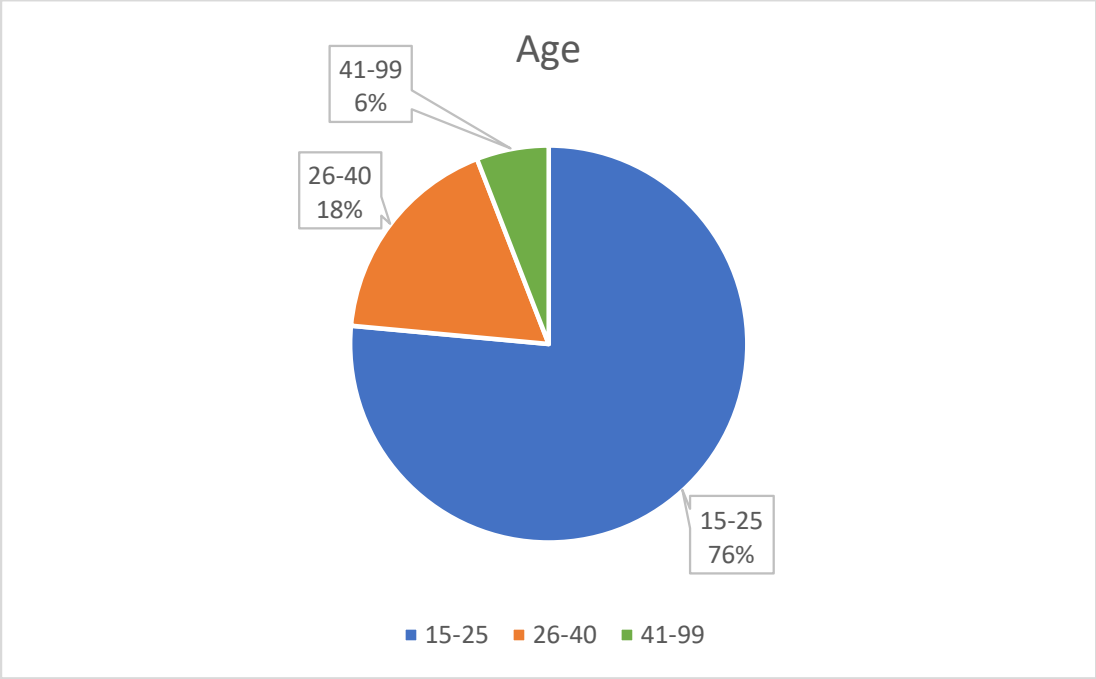

Figure 6.3: Age of participants (Source: author)

36 people chose Male. Only 5 people choose the "Prefer not to say" option. 65 of the participants were in the 15-25 age range while the 26-40 and 41-99 categories were significantly lower at 15 and 5, respectively. These results relate to questions 1-3.

Question 4

68 people chose the student option, about 80% of the total 85. 4 people selected "Professor" and 13 selected "Other".

Question 5

In building Z, 55% of the respondents used a first-floor restroom, 23% used a ground floor restroom, 16% a third-floor restroom, and 6% a second-floor restroom. There were no results from the fourth, fifth, or sixth floor.

In building D, 34% of the participants used a first-floor restroom with the fourth floor a close second at 28%. 17% used a second-floor restroom, 10% on the sixth floor, 7% on the third floor, and 3% on the fifth floor. There were no results from the ground floor restrooms.

Question 6

75% of the respondents used the paper towels to dry their hands, a superior amount more than the hand dryers at only 14%. 7% used both methods while 4% used neither.

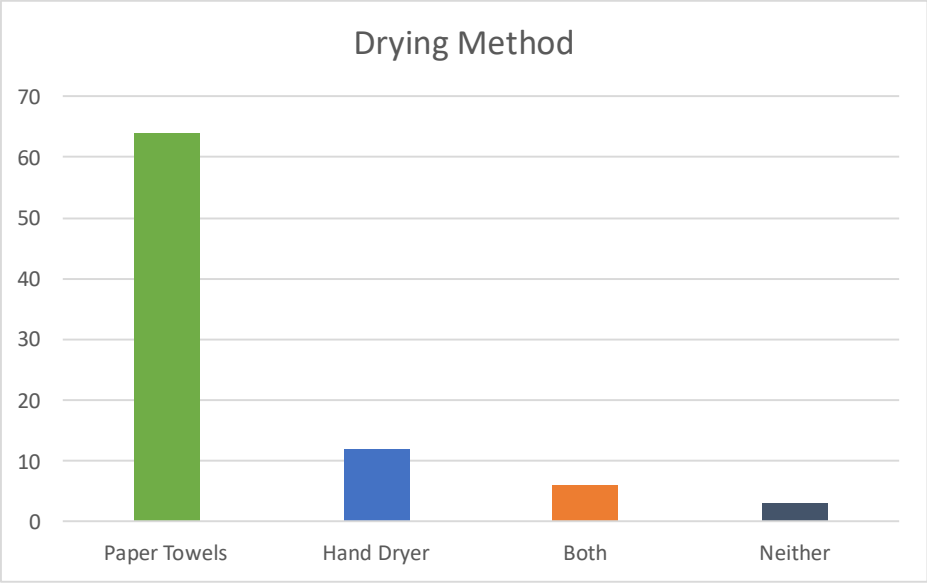

Figure 6.4: Usage of different hand drying methods (Source: author)

Question 7

64 people chose paper towels as their hand drying method, with 6 using both methods. A majority at 53% of the respondents used two sheets, as seen in Figure 6.5. The next most common amount was three sheets at 27%, then one sheet at 14%, four sheets at 4%, and only 1% used 5+ sheets.

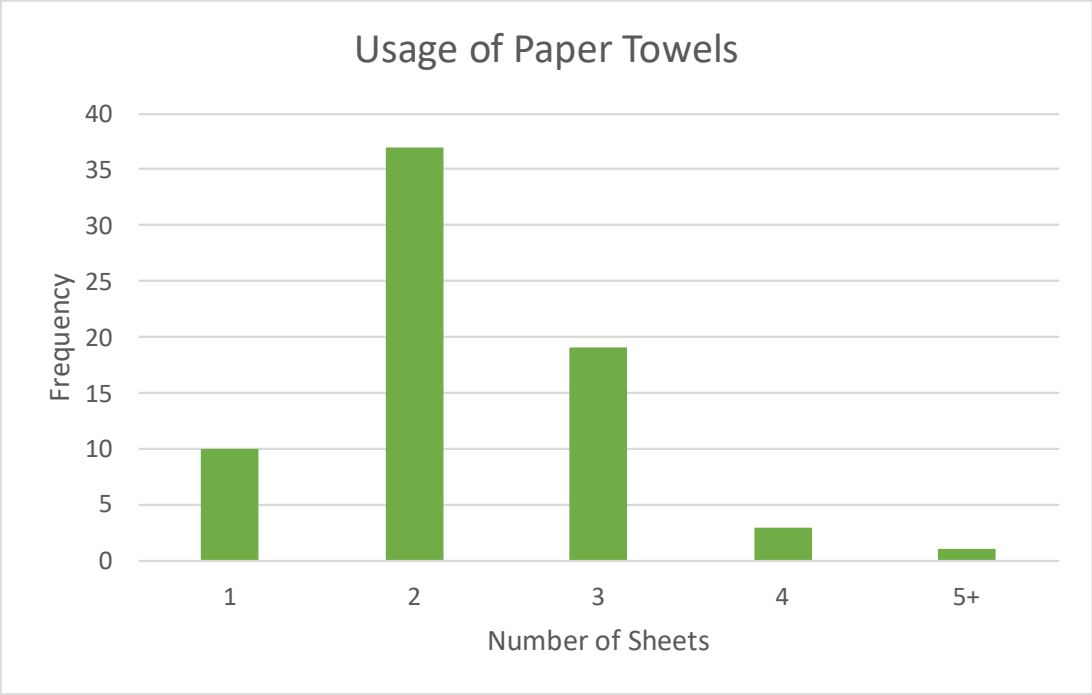

Figure 6.5: Number of sheets of paper towels used per person (Source: author)

Question 8

12 people chose to use the electric hand dryer, with again 6 people using both methods. Of those 18, 50% used the dryer for a duration of 6-10 seconds, 28% for 1-5 seconds, 11% for 11-15 seconds, and 6% for both 16-20 seconds and 21-30 seconds. There were no responses with 30+ seconds.

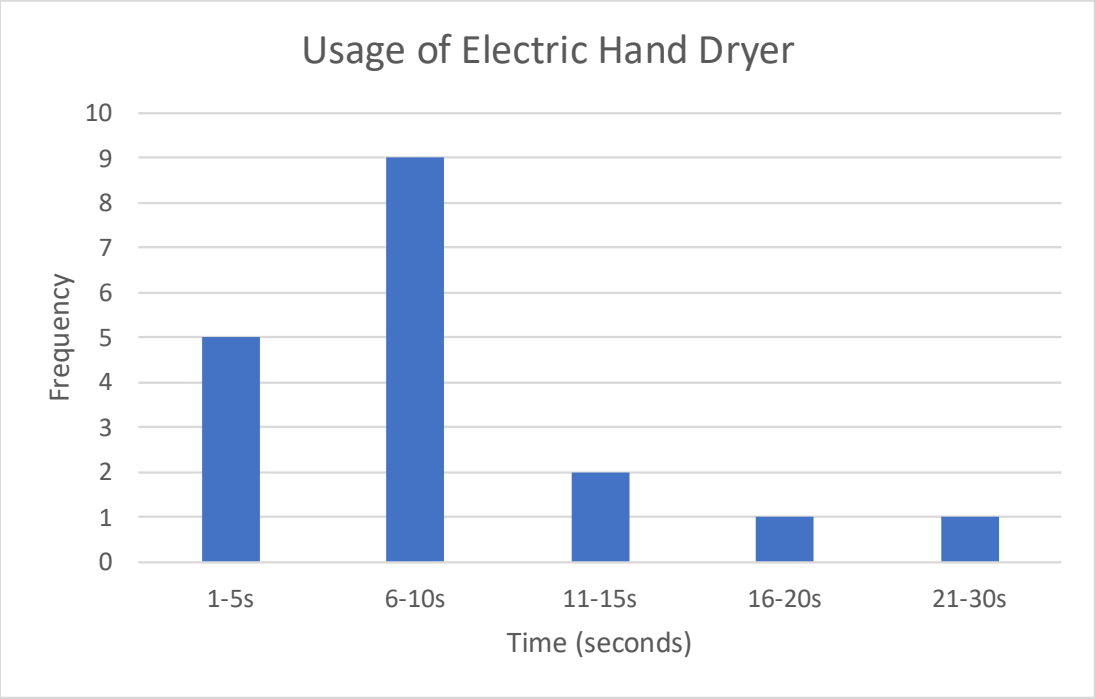

Figure 6.6: Duration of electric hand dryer use per person (Source: author)

Question 9

Out of the 85 respondents, 71 people chose paper towels as their preferred drying method with majority stating efficiency as the reasoning, along with other reasons such as hygiene and noise. 13 people chose the electric hand dryer as their preference with reasoning such as decreased waste and efficiency. Only 1 person stated neither method was preferred.

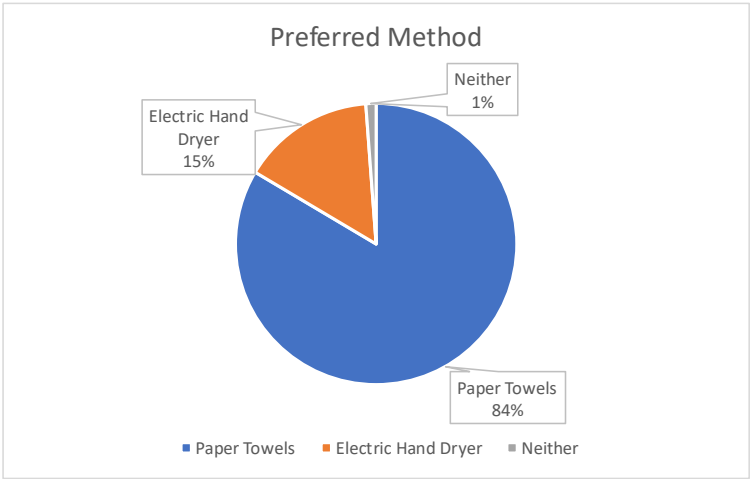

Figure 6.7: Preferred hand drying method (Source: author)

Question 10

33% of people responded that electric hand dryers are more environmentally friendly, while 23% stated the dryers are not. Reasons for yes included less waste and lower ecological effects; on the other hand, reasons for no included electricity usage and/or source, and hygiene. 27% chose maybe and 17% said unsure, with only 1% saying both methods are similar in environmental impact. The reasoning for choosing maybe depended on electricity usage and/or source, waste, and hygiene.

Question 11

59 people stated that, in terms of hygiene, paper towels were the preferred drying method. 12 chose hand dryers and 14 stated they were unsure of which method was more preferable.

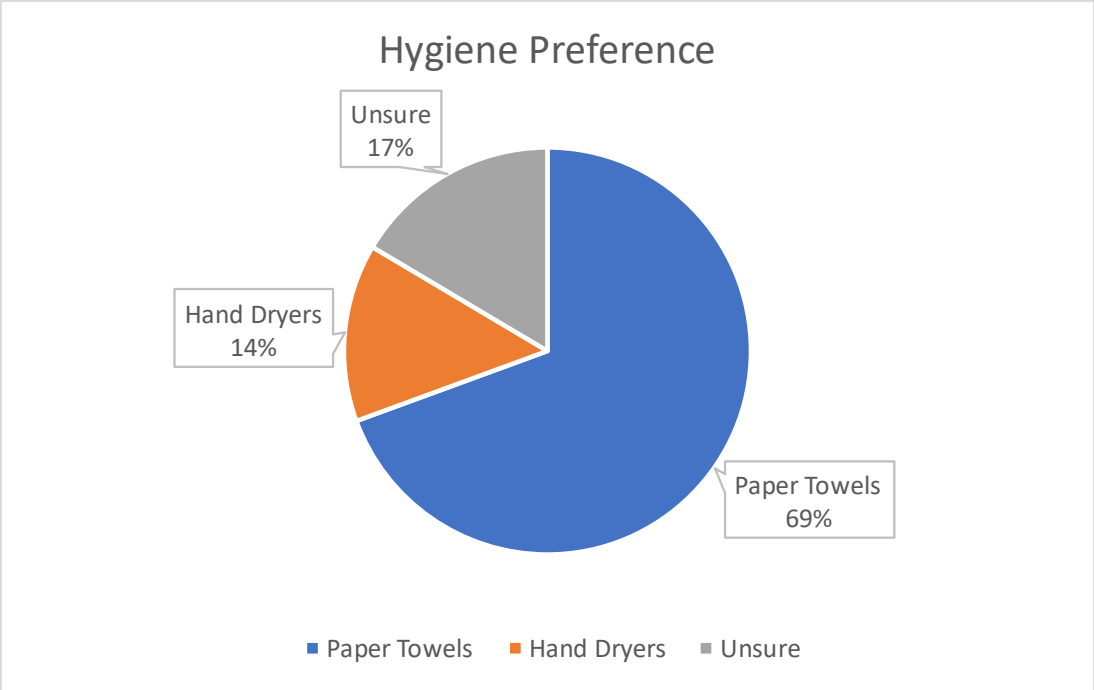

Figure 6.8: Hygiene preference of different drying methods (Source: author)

Question 12

When asked whether businesses are more environmentally aware if electric hand dryers are present in the restrooms, 17 people stated yes and 22 stated no. 46 people, the vast majority, chose unsure.

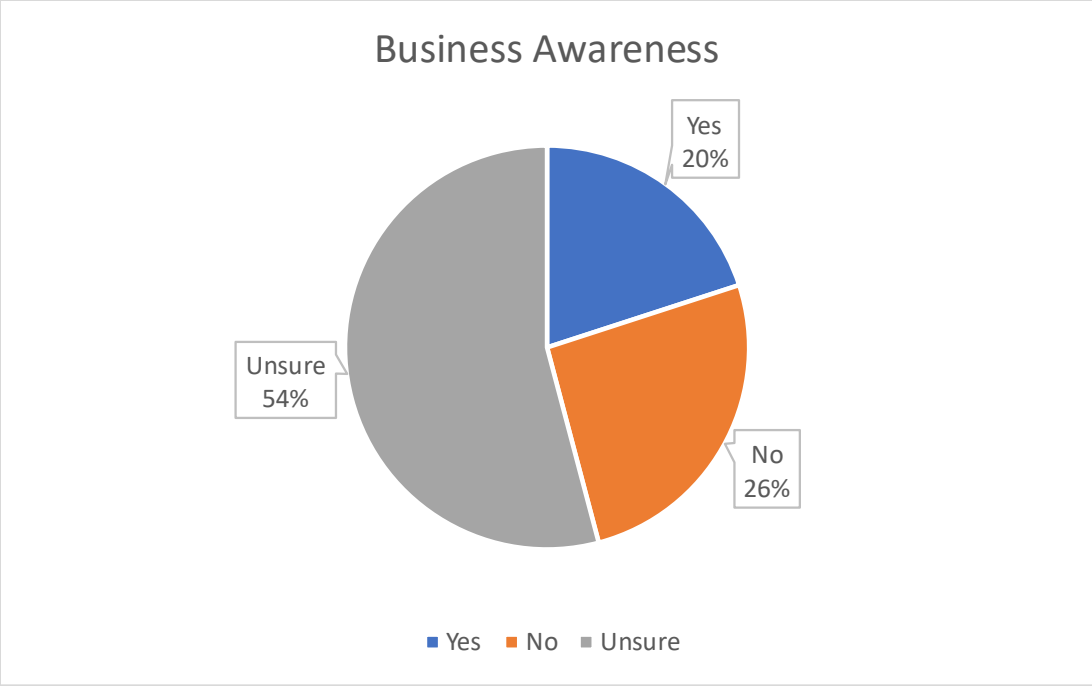

Figure 6.9: Public opinion on business awareness if electric hand dryers are present (Source: author)

Question 13

56 of the respondents considered the electric hand dryers to be the more economical option, while 29 people chose paper towels as the more logical financial option.

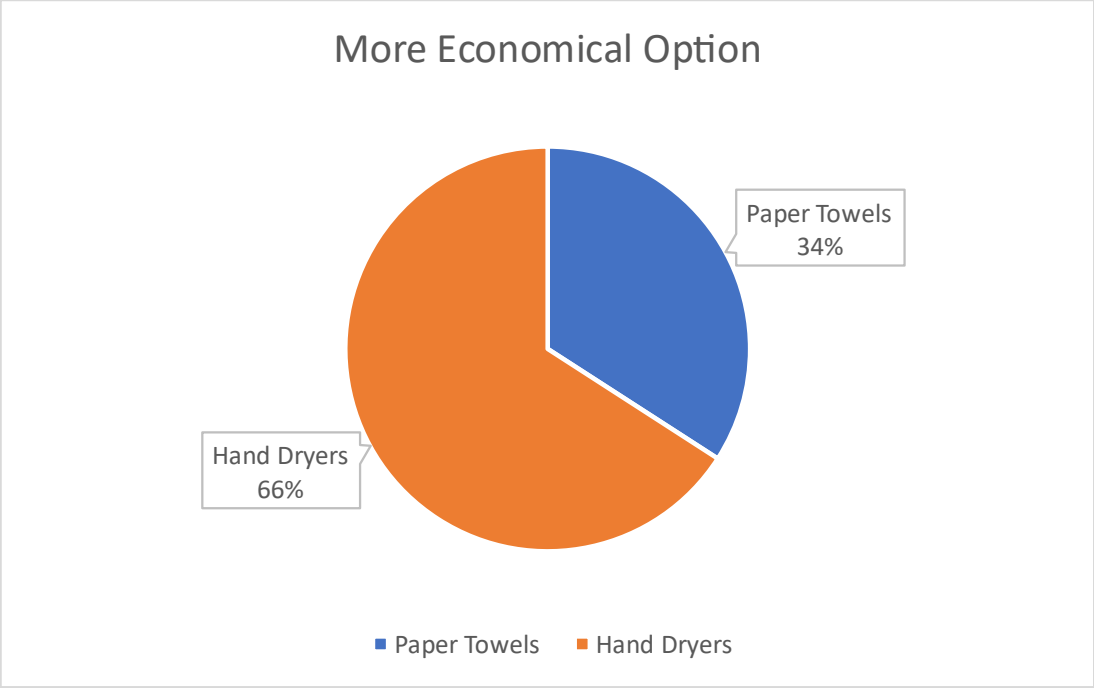

Figure 6.10: More economical option between hand drying methods (Source: author)

Question 14

57 of the participants chose the high speed electric hand dryers as the more efficient option. 7 chose the hot (warm) air dryer as the more efficient dryer and 21 said neither of the options were efficient.

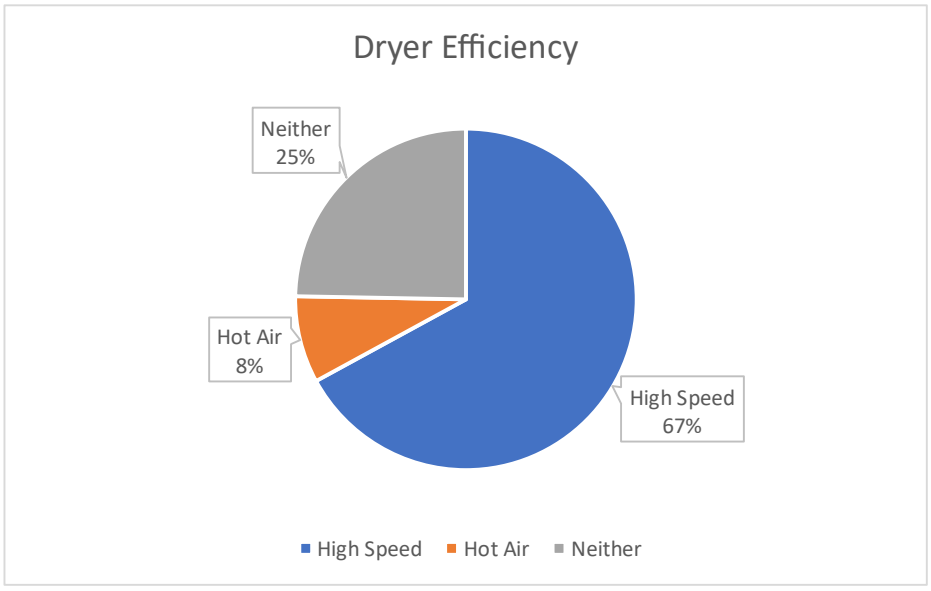

Figure 6.11: Efficiency of hot air dryers versus high speed dryers (Source: author)

Question 15

In the situation where paper towels are the only drying option, 54% of respondents said this is the more effective drying option. 13% said only paper towels are a more economical strategy, while 15% said the business is not keeping up with the current trends in hand drying advancements. 13% chose both more economical and more effective, 2% chose both not keeping up with current trends and more effective option, and 1% chose not keeping up with the current trends and more economical option. Only 1% selected all three.

Question 16

In a business where only hot air dryers are in place, 47% of respondents stated that the dryers were most likely there for a long period of time. 29% of people said that the hot air dryers are the more effective option, while 7% said the business is not keeping up with current trends. 7% of participants selected both not keeping up with current trends and the dryers have been in place for a long time. 5% stated the hot air dryers have been in place for a long time and are the more effective option, and 1% said the business is not keeping up with current trends and the hot air dryers are the more effective option. 4% chose all three options.

Question 17

When only high speed dryers are available, 26% of respondents said the business chose the dryers as the high speed type are the most modern technology. 20% said the business is only keeping up with current trends, while 18% said the high speed dryers are the most effective option. 12% of people said the business is keeping up with current trends and the high speed dryers are the most modern technology. 8% stated the dryers are the most modern technology and the most effective drying method, and 5% said the business is keeping up with current trends and the dryers are the most effective drying method. 12% of participants chose all 3 options.

7. Discussion

The literature reviewed in chapters 3 and 4 covered all material relating to the environmental and economic impacts of paper towels versus electric hand dryers. The noise level of the hand dryers can be quite high and tends to deter use in public restrooms. In terms of hygiene, there exists some controversy as paper towels have lower bacterial aerosolization capacity, but the electric hand dryers transfer less bacteria directly to the hands, especially if HEPA filters are installed. Additionally, the differences in hand dryers and paper towel types could change the hygienic performance of each, although paper towels are the recommended method for sensitive settings such as hospitals.

When entire life cycles are considered, from production to disposal, paper towels tend to have a lower sustainability due to higher emissions, more waste, and greater pollution. In particular, the manufacturing, transportation, and disposal stages trended higher for paper towel impacts than the hand dryers. While the hand dryers produced a greater impact during use, especially if fossil fuels contribute a majority in the energy grid, the extended lifetime and little maintenance needed during that lifetime decrease the hand dryer impact in the transportation and waste scenarios. On the other hand, hand dryers have significant impacts in the land use and minerals categories due to mining needs. With today's technology and advancements, the waste options for both drying methods have become more environmentally friendly: paper towels have the capability for recycling and composting, although composting is the better solution due to lower emissions and the added benefit with the use as fertilizer, while hand dryers have had the recent developments in recovery and reuse/recycling of electronic parts and the plastic and metal portions of different devices.

With respect to the financial scenarios for the drying methods, hand dryers are typically the most expensive option initially due to high production costs and more limited materials, with paper towels less expensive at first but long-term the more costly purchase due to continual maintenance and disposal costs over its lifetime; the number of daily uses does play a role in which is the more economical method, as does the source of electricity for the hand dryers during use.

The survey results show 84% of people prefer paper towels to hand dryers with one of the reasons behind that being hygiene, with 69% of people stating the paper towels are better for hygiene, although it is unclear whether this is backed by evidence or primarily opinion based. Additionally, majority of people believe the electric hand dryers are the more environmentally friendly drying method but 75% still chose to use the paper towels with the main reason being efficiency, although the hand dryer use shows that majority of people use the dryer for only 6-10 seconds and do not use the dryers for the recommended 30+ seconds to properly dry the hands. This shows a conscious decision to choose a quicker and more convenient method instead of the agreed more eco-friendly drying option. The type of hand dryer could play a role in this decision as well, as 67% of people chose the high speed dryer as more effective than the hot air dryer, with the hot air dryer being much more common in public restrooms and could be a deterrent to users. Also, when asked whether businesses are more environmentally conscious by installing hand dryers instead of paper towels, majority stated the dryers are merely the most modern technology (in the case of the high speed dryers) or have been there for a long time (in the case of the hot air dryers). Half the participants stated they are unsure if installing dryers is environmentally aware and a quarter stated installation is not at all, reflecting on the public opinion that the environmental effects of hand dryers is still thought to be equal to or worse than paper towels. With respect to the economics of the drying options, 66% of participants chose the electric hand dryers and only 13% said paper towels are the more economical choice in a public restroom only offering the towels, indicating the public view coincides with the evidence that dryers have the potential to be more financially logical if placed for long periods of time in areas of high-traffic and high-use.

Overall, the hypothesis "*there is a perceived difference as to the environmental and economic impact of both systems* [paper towels and electric hand dryers] *by the consumer*" proves to be half correct. Majority rightly say the electric hand dryer has more economic benefits but believe paper towels have the lower environmental impact, contrary to the evidence provided stating hand dryers are more sustainable especially in the long term. Although the better hygiene belongs to the paper towels,

this is significantly outweighed by the environmental and economic advantages of implementing hand dryer use.

8. Conclusion

As humanity moves towards sustainability on first the national and then the global scale, knowledge of better practices and technological advancements needs to be taught to the public to increase adherence to eco-friendly habits. The washing and drying of hands is an extremely common practice in the 21st century and the approach to the impacts, both environmentally and economically, needs to become streamlined to be the least detrimental in both senses. The current public opinion presented in the survey taken on the university campus shows the need for education on the ecological effects of different drying methods as many believe paper towels are the best option in spite of the advantages of electric hand dryers, and the view on the preferred drying methods needs to be shifted away from continual use of paper towels in non-sensitive atmospheres. In addition, places of business with large amounts of traffic circulating through the restrooms need to be considering the installation of electric hand dryers, particularly high speed dryers, as a substitute for paper towels in order to increase sustainability and promote green practices.

9. Future Work

Further research should be conducted to determine the best hand drying approaches, such as the best length of time to use a hand dryer and the best way to transition from the conventional paper towels to the newer technology of electric hand dryers in order to make the public more accepting of this alternative choice. Additionally, impacts of implementing electric hand dryers as the only option in restrooms should be analyzed for each individual business as to determine the most optimal installments and to incentivize businesses to continue moving towards greener choices.

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10. Appendix

10.1 Hand Drying Preference Survey – English

* Mandatory

1) Nationality *

_____

2) Gender *

- Male
- Female
- Prefer not to say

3) Age *

- 15-25
- 26-40
- 41-99

4) Profession *

- Student
- Professor
- Assistant
- Other

5) Which restroom was used? *

- Z 022
- Z 023
- Z 024
- Z 112
- Z 116
- Z 230
- Z 231
- Z 232
- Z 237
- Z 238
- Z 331
- Z 332

- Z 333
- Z 340
- Z 341
- D 105
- D 106
- D 109
- D 111
- D 205
- D 206
- D 209
- D 211
- D 303
- D 305
- D 308
- D 310
- D 403
- D 405
- D 408
- D 410
- D 505
- D 510
- D 605
- D 610

6) Which drying method was used? *

- Paper towels
- Electric hand dryer
- Neither

7) If paper towels were used, how many sheets? *

- None
- 1
- 2
- 3
- 4

- 5+

8) If an electric hand dryer was used, for about how long? *

- 0 seconds
- 1-5 seconds
- 6-10 seconds
- 11-15 seconds
- 16-20 seconds
- 21-30 seconds
- 30+ seconds

9) Which method is your preference? Why? *

_____

10) Do you believe electric hand dryers are more environmentally friendly? Why? *

_____

11) Which do you believe is more hygienic? *

- Electric hand dryers
- Paper towels
- Not sure

12) Do you feel that a business or school that offers electric hand dryers is more environmentally aware? *

- Yes
- No
- Not sure

13) Which option do you feel saves more money? *

- Paper towels
- Electric hand dryers

14) Do you feel that hand dryers that blow warm air or hand dryers that use high speed air are more effective? *

- Warm air dryers
- High speed dryers
- Neither

15) If you visit a place of business and they only have paper towels available, does this tell you that: *

- The business is not keeping up with current trends.
- The business believes paper towels are more economical.
- The business believes paper towels are more effective and/or hygienic.

16) If you visit a place of business and they only have hot air hand dryers available, does this tell you that: *

- The business is not keeping up with current trends.
- The business has chosen to provide hot air hand dryers because they have been in place for a long time.
- The business believes the hot air hand dryers are more effective and/or hygienic.

17) If you visit a place of business and they only have high speed hand dryers available, does this tell you that: *

- The business is keeping up with current trends.
- The business has chosen to provide them because they represent the most modern technology.
- The business believes the high speed hand dryers are more effective and/or hygienic.

10.2 Hand Drying Preference Survey – Czech

1) Státní příslušnost *

_____

2) Pohlaví *

- Muž
- Ženský
- Radši neříkej

3) Věk *

- 15-25
- 26-40
- 41-99

4) Povolání *

- Student
- Profesor

- Asistent
- Jiny

5) Která toalety byla použita? *

- Z 022
- Z 023
- Z 024
- Z 112
- Z 116
- Z 230
- Z 231
- Z 232
- Z 237
- Z 238
- Z 331
- Z 332
- Z 333
- Z 340
- Z 341
- D 105
- D 106
- D 109
- D 111
- D 205
- D 206
- D 209
- D 211
- D 303
- D 305
- D 308
- D 310
- D 403
- D 405
- D 408

- D 410
- D 505
- D 510
- D 605
- D 610

6) Jaká metoda sušení byla použita? *

- Papírové ručníky
- Elektrický osoušeč rukou
- Žádná

7) Pokud byly použity papírové ručníky, kolik kusu? *

- 0
- 1
- 2
- 3
- 4
- 5+

8) Pokud byl používán elektrický osoušeč rukou, jak dlouho? *

- 0 sekund
- 1-5 sekund
- 6-10 sekund
- 11-15 sekund
- 16-20 sekund
- 21-30 sekund
- 30+ sekund

9) Které metodě dáváte přednost? Proč? *

_____

10) Myslíte si, že elektrické osoušeče rukou jsou šetrnější k životnímu prostředí? Proč? *

_____

11) Co je podle vás lepší z hygienických důvodů? *

- Elektrické osoušeče rukou
- Papírové ručníky
- Těžko říct

12) Máte pocit, že firma nebo škola, která nabízí elektrické osoušeče rukou, je šetrnější k životnímu prostředí? *

- Ano
- Ne
- Těžko říct

13) Která možnost podle vás ušetří více peněz? *

- Papírové ručníky
- Elektrické osoušeče rukou

14) Máte pocit, teplovzdušné osoušeč, nebo osoušeče rukou, které používají vysokorychlostní vzduch, jsou účinnější? *

- Teplovzdušné osoušeč
- Vysokorychlostní osoušeč
- Žádná

15) Pokud navštívíte podnik a mají k dispozici pouze papírové ručníky, znamená to, že: *

- Podnik nedrží krok se současnými trendy.
- Podnik věří, že papírové ručníky jsou šetrnější.
- Podnik věří, že papírové ručníky jsou účinnější a/nebo lepší z hygienických důvodů.

16) Pokud navštívíte podnik a mají k dispozici pouze horkovzdušné osoušeče rukou, znamená to, že: *

- Podnik nedrží krok se současnými trendy.
- Podnik se rozhodl poskytovat horkovzdušné osoušeče rukou, protože jsou na místě po dlouhou dobu.
- Podnik věří, že horkovzdušné osoušeče rukou jsou účinnější a/nebo lepší z hygienických důvodů.

17) Pokud navštívíte podnik a mají k dispozici pouze vysokorychlostní osoušeče rukou, znamená to, že: *

- Podnik drží krok se současnými trendy.
- Podnik se rozhodl je poskytnout, protože představují nejmodernější technologie.

- Podnik věří, že vysokorychlostní sušičky jsou účinnější a/nebo lepší z hygienických důvodů.