

# Innovative Solutions for Reducing Waste at Skidmore College

Analyzing the Carbon Footprint & Economics  
of  
Paper Towels vs. Electric Hand Dryers

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**Acknowledgements:**

We would like to thank our Skidmore College professors, Andrew Schneller, Bob Turner, Kurt Smemo, and Karen Kellogg. We would also like to thank the entire procurement office, sustainability office, and Skidmore College for granting us student opportunity funds in order to complete these experimental analyses.

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## WASTE REDUCTION AND SUSTAINABILITY AT SKIDMORE COLLEGE

### **Abstract:**

The purpose of this capstone project is to create the most culminating analysis of all of the available hand drying methodologies, and utilize this research in order to integrate the most environmentally sustainable and economically stable hand drying installation within Skidmore's establishments and specifically the new Center for Integrating Science building. The new 200,000 square foot CIS building will encompass 23 teaching and 46 research labs, 22 instrumentation rooms, 41 project and preparation spaces, five technology suites, 15 classrooms and meeting rooms, as well as social, display, and other public areas. We analyze the integration potential for this new building as well as Skidmore College entirely within this investigation. Throughout this analysis, the criteria that will be examined will be the structural acoustics of the allotted space, noise in decibels, backlight photography, cradle to cradle analysis, and a waste audit.

### **Introduction:**

Humans are beginning to reach a point in civilization where we do not fully consider the cradle-to-cradle reactions and consequences of our actions. This research addresses the paper waste and energy consumption while hand washing in restrooms. The current debate that is ongoing on college campuses is about whether or not paper towels are the most environmentally friendly, economically sound, and efficient at eliminating harmful germs and bacteria. This research investigates whether or not electric hand dryers are recognized as a viable alternative to paper towels currently utilized at Skidmore College. This is an extremely pertinent issue because Skidmore is landfilling on average 17,800 lbs. of paper towels from restrooms across the campus. In order to eliminate this source of waste, the potential negative effects of using hand

dryers must also be addressed. The main concerns about electric hand dryers that we plan to investigate are in regard to their material costs, maintenance costs, installation, overall energy consumption, noise pollution as well as their ability to eliminate germs and bacteria. In order to properly analyze this situation, we must understand the sanitary and environmental efficiency of both paper towels and electric hand dryers. Within this study, we also explore the existing literature of the situation which is well balanced between both sides of the argument; paper towels and electric hand dryers.

Our research facilitates an economic analysis that bolsters the validity of our argument on a 10-year plan. In regard to all environmental action; funding, sound economics, stakeholders, and ease of installation all play an important role. This research is driven by economic measures in order to insure that the findings of this research are not disregarded by our stakeholders.

The current mechanism in place on Skidmore College's campus is not very efficient or environmentally friendly. Our restrooms all utilize paper towels without any other alternative provided. It is important to also note that all of our restrooms waste is currently landfilled (not recycled or composted) and placed within a dump for the rest of eternity. Our conservation ethic led us to the question of "why can't these materials be recycled"? This question raises one of the fundamental issues for the utilization of paper products within restrooms. The fact of the matter is that there's hardly any fiber left in common paper towels to recycle (MIT, 2011). If we continue to utilize these inefficient means of hand drying, we will continue to experience negative environmental effects on a communal, national, and global scale. This is an extremely important environmental and sustainability issue because it does not have any boundaries in regard to responsibility or resource utilization; everyone uses the restroom. This is why we believe that this research can be recognized on a large scale and used to potentially reduce the

immense amount of waste created within restrooms on college campuses. On a more local scale, Skidmore college is currently very interested in bolstering campus sustainability, and has purchased the energy permits for the local solar facility for the next 22 years, as well as made commitments to reduce emissions through many other innovations such as micro-hydro, passive solar, geothermal, and building retrofits (bulbs and building materials). This is why we find a long term economic analysis reasonable. We're also interested in influencing the bathroom components of the soon to be build Center on Integrative Sciences (CIS building) on Skidmore Campus within the near future.

**Figure 1: Analysis of Paper Towels (PT's) vs. Electric Hand Dryers (EHD's)**

	<b>Paper Towels (Numerous Types / Materials)</b>	<b>Electric Hand Dryer (++ Models)</b>
Waste	Physical Waste / C2C Waste / Maintenance	No Physical Waste (besides structural Materials)
Electricity	Electricity-Free	Requires Electricity
Germ Elimination	More Efficient	Less Efficient (Getting Better)
Germ Distribution	Into Trash Can / High Sanitary Grade	Blows Germs / Bacteria (1-3 Meters)
Installation Fees	Low but Continuous	High but flat-fee (or close to)
Required Service	High	Low
Volume / Noise	Low - Medium	High

The figure above describes the factors that we plan to consider throughout our economic analysis. It is important to recognize the overall cradle-to-cradle inputs that occur throughout these hand drying mechanisms. The economic analysis investigated the process of making paper towels, what are paper towels made of (fiber contents -- Virgin vs. post-consumer recycled materials), cost of paper towels, how many rolls/boxes of paper towels does Skidmore College use per semester/year, how far away is the landfill that the paper waste is being transported to, what kind of vehicle is transporting the waste, transportation costs of PT's, packaging costs of paper towels, how long will they take to degrade in a landfill, will they compost in a landfill, is

there an economic benefit of having less noise pollution (surveys). In order to properly investigate this issue, we must consider all facets of the paper towels, creation to destruction.

These inputs for paper towels are going to be directly compared to the cradle to cradle use of electric hand dryers. In specific regard to our economic analysis, our research considered questions like what materials are the EHD made from, what are the initial purchasing and installation costs of EHDs, how much energy do EHDs use, what kind of energy would Skidmore College supply the EHDs with, what is the overall cost of maintenance, what are people's willingness to pay for less noise pollution, how many places on campus are actually feasible locations to place EHDs.

The purpose of this research is to better understand if EHD's are more efficient both economically and environmentally. Without economic incentives, this will never gain enough support to be recognized on a large scale by institutions such as Skidmore College and other Colleges or Universities. After we have created this economic comparison, the secondary motive of the study will be analyzing germ accumulation and restroom sanitation.

Sanitary safety is the most important aspect of our research. We need to analyze how effective these two hand drying methodologies are. In order to answer this question, we must conduct experimental studies on campus in order to compare PT's and EHD's individual sanitation efficiencies. We plan to recruit Skidmore College students to participate within our study where they are told to use one of these two hand drying mechanisms. We want to examine common bathroom behaviors and actually determine how effective hand dryers are and what kind of positive change can be made. Bacterial prevention is the most important factor and many literature sources say that electric hand dryers spread more germs than PT's. We also plan to analyze the overall sanitary conditions of Skidmore's restrooms by using a UV light to detect

germs and bacteria. We believe that this facet of our investigation will lead to insightful realization towards the improvement of the overall sanitary condition of our restrooms.

A third important topic which we plan to investigate is the noise pollution created by the electric hand dryers. This is an important issue among the teaching faculty because many EHD's are loud, exposing teachers and students as well as those employees who clean the facilities to loud and irritating noise. Since the majority of the restrooms across campus are located near classrooms and offices, noise pollution is an extremely relevant factor, and expressed during interviews as a concern by Skidmore's Dean of Sustainability, Karen Kellogg. This is important because while on a college campus, there are often classes, meetings, and presentations that are occurring throughout the day. The noise created by the electric hand dryers have the potential to be a distraction and disrupt students and faculty. We plan to visit facilities in Saratoga where electric hand dryers are installed in their restrooms and measure the noise with a decibel reader to quantify the noise. This study will be conducted from various distances and we will be able to more efficiently recognize which locations we could potentially install EDH's on Skidmore Campus and beyond. These are the three overarching measures that we will be analyzing throughout our capstone research project.



### **Research Questions:**

- 1. How would Skidmore's carbon footprint be affected if we transitioned to EHD's?**
- 2. If any, what are the economic benefits of utilizing electric hand dryers in comparison to using paper towels?**
- 3. What are the perceptions of Skidmore College's Student Body and other academic institutions?**
- 4. Are EHD's compatible within academic environments - Analyze possibility of behavioral change?**
- 5. What is the feasibility of composting Skidmore's paper towel waste?**

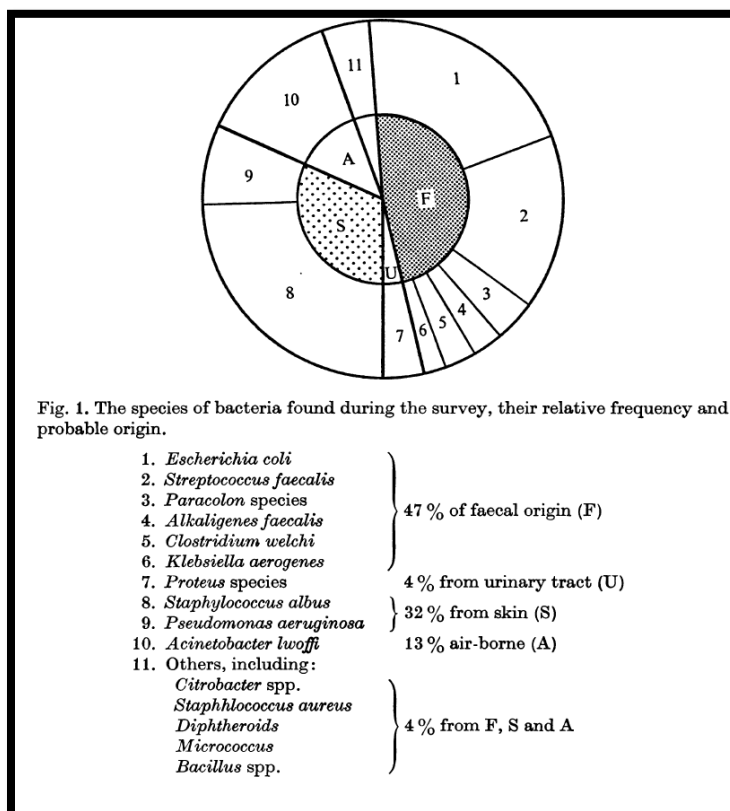
## **Literature Review**

The literature review and research analysis is particularly important for this study because we would like to build upon prior studies and help lead Skidmore College towards the most sustainable yet economically beneficial future. Our analysis of the available literature has led us to conclude that a particular focus towards sanitary efficiency, waste, overall costs, electricity, noise, cradle-to-cradle and product analyses will most efficiently help solve this ongoing debate between paper towels (PT's) and electric hand dryers (EHD's).

### **Sanitary Efficiency:**

In order to conduct bacterial experiments, the basics of restroom sanitation must be initially addressed in order to properly analyze the situation. Within Mendes and Lynch's, *A bacteriological survey of washrooms and toilets*, the overall types of bacteria that are commonly found in restrooms as well as the common origin are discussed. Within this analysis of bacterial flora present within 130 male and female washrooms, there were eleven groups of bacteria that were overwhelming common in origin and sustenance. Within the figure below, the overall origin of bacteria was found to be largely from fecal matter, then skin, air-borne, and the urinary tract (Mendez & Lynch, 1976). This specific study is influential towards our research because it provides an overall overview of the most common bacteria within restrooms as well as their relative rates of spawning. This information has served as a template for research after this research was conducted in 1976.

Figure 2: (Mendez & Lynch, 1976)



Many stakeholders within the scientific and medical community suggest that from a hygienic viewpoint, paper towels are superior to electric hand dryers (Huang, pp.795). When considering the overall transmission of bacteria, it is important to note that growth is more likely to occur within a wet or moist environment in comparison to dry. This characteristic of bacterial growth needs to be further researched by EHD manufacturers in order to promote their products which they believe to be more sustainable.

The promotion of the most sanitary means of hand drying should always be prioritized as the most important goal of all similar studies. One of the major discrepancies that is creating a bias against EHD's is the theory that they spread harmful bacteria throughout the air as they

function. This form of airborne cross contamination was examined within Dr. Huang's study which compared the bacterial dispersal of both hot air dryers and paper towels. This study found that the standard electric hot air dryer effectively causes a dispersal of bacteria within the radius of approximately three feet from hot air dryers. It was also found that some of the bacterial particulate matter was blown onto the investigator's laboratory coat. (Huang, pp 794). In comparison to EHD's within this study, the paper towels did not spread any airborne bacteria. This specific information was helpful in regard to the overall scope of this research because it proved that the use of EHD's causes a dispersal of bacteria throughout the air. One major concern of our research was regarding the distance of bacterial dispersal. This study proves that the bacteria is not spread in a rampant manner throughout the entirety of a restroom; which is a common concern of many on this particular matter.

Another interesting aspect of this article also identifies a stronger vector of bacterial dispersal within the bathroom that is often overlooked. Dr. Huang's study was able to identify that every time a toilet is flushed, a fine aerosol mist is dispersed as far as six meters away (Huang, 794). This factoid is interesting because it invalidates EHD's bacterial dispersal arguments partially. This mist, which is directly from the source of fecal bacteria, is dispersed three times further, and is still overlooked and not perceived as an issue of public health. Within the Mendez & Lynch experiments, it was found that 47% of bacteria within restrooms come from fecal origin. This statistic draws upon a sanitation issue that could potentially affects our public health (Mendez & Lynch, 1976). Since this fecal spraying from toilets is not addressed by scientists as a concern of public health, the bacterial distribution caused by EHD's could be insignificant as well.

In comparison to Huang's study, Redway found that the jet dryers, which force air "through two continuous apertures the width of an eyelash - creating sheets of air travelling at 400 miles per hour" (Redway, 2008, pp. 31). These jet dryers were found to spread bacteria throughout the air more than 6 feet. This value is alarmingly different in comparison to Huang's and led our research group to believe that specific model type is immensely important when considering feasibility of our project on Skidmore College campus. The bacterial dispersal within Redway's experiment was found to be more than double Dr. Huang's results. This discrepancy proves that experimental environment and research methods need to be collaboratively assembled and measured in a standardized manner in order to reach an acceptable verdict to this controversial discussion.

This overall discrepancy fuels the debate for why EHD's aren't used. Sanitary efficiency is the primary motive of this investigation, but it is import to acknowledge that EHD utilization functions as a form of technological innovation in that will revert climate change. We as an academic, scientific and medical community cannot overlook or disregard any possible vector to improve our personal impacts towards environmental sustainability. Large scale waste reductions as well as economic benefits can be obtained if we are able to create solutions to the adverse effects of EHD utilization. Apart from the concerns about EHD's sanitary efficiency, literature regarding noise and electrical consumption will be analyzed in comparison to the cradle-to-cradle processes of paper towels in order to resolve these discrepancies.

### **Noise (Decibel Anlaysis):**

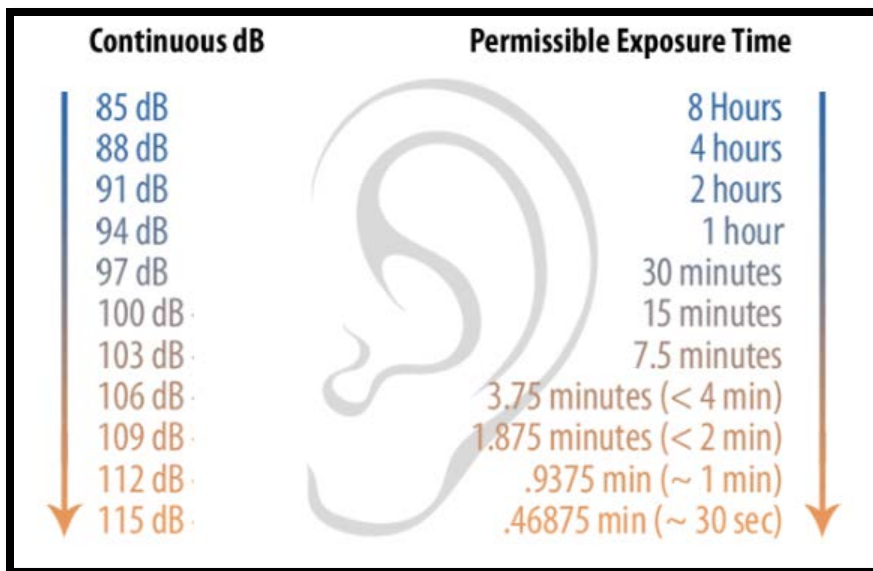
EHD's are commonly very loud and are not suitable for utilization in specific areas. Within our study, which is directly examining the utilization of EHD's on a college campus, this

factor is one of the most deterring. Within Dr. Huang's study, a decibel reader was used to analyze the overall volume of numerous devices. The mean decibel level of EHD's within this study was found to be 94 dB from a distance of one meter. These measurements were found beneficial towards our study because this form of volume measurement can be easily replicated. This base model of volume detection will be used as the model for our experimental design later in the report.

Within Huang's analysis, researchers took decibel measurements from one meter as well as two meters away. This experimental design also investigates the volume of multiple EHD's functioning at the same time. This is an important aspect of the overall scope of our research that we at first did not consider. Within Huang's study, it was found that when two jet air dryers were used at the same time, the mean decibel reading was 92 dB from two meters away (Huang, 2012).

These decibel recordings within Huang's study raise concern towards hearing health. On the Dangerous Decibels website, it is quoted that for every three decibels over 85 dB's, the permissible exposure time before possible damage is cut in half. This statistic is reported within figure three below. Within our experimentation, we will be using this chart as a guide to analyze individual model's dB readings.

**Figure 3: Decibel Safety (Dangerous Decibels, 2016)**



This is an extremely important observation because the type of electric hand dryer, the Xlerator, has been proven to be at the very loudest of 90 dBs. This proves that these hand dryers could not put anyone in danger.

#### **Electrical Efficiency: (United States' Grid)**

When considering the overall feasibility of large-scale EHD implementation, it is important to consider the overall efficiency of the source of power. Even though the United States' national grid is currently improving, it is still highly powered via fossil fuels and coal. This United States relies upon coal to power about forty-five percent of the total energy supplied to the grid (Montalbo, 2011). This grid also functions accordingly to a continuous peak-schedule without any battery storage capabilities. This large inefficiency creates a difficult obstacle for EHD's to combat due to the fact that they rely exclusively on electricity. For our project on Skidmore College Campus, our energy source is more ecologically sustainable than the common consumer and is boosted in power from a small off-campus hydro plant, off-and-on-campus solar facility as well as many geothermal installations. With the help of these facilities Skidmore is

being charged .0505 cents for every kWh, in comparison to New York States rate of .14 cents per kWh (Kellogg, 2017).

Within figure 4 below, the overall effects of seven hand drying techniques are compared in regard to global warming potential. Montalbo importantly recognizes that the impact from the utilization of paper towels does not change along with our grid-efficiencies. Figure 4 very importantly acknowledges that standard dryers create nearly twice as much harm towards the environment if the United States is powered strictly by coal. This is extremely pertinent due to the United States' current political atmosphere; which is expected to drastically increase in coal production and utilization.

**Figure 4 : Possibilities Via Grid Efficiencies (Montalbo, 2011)**

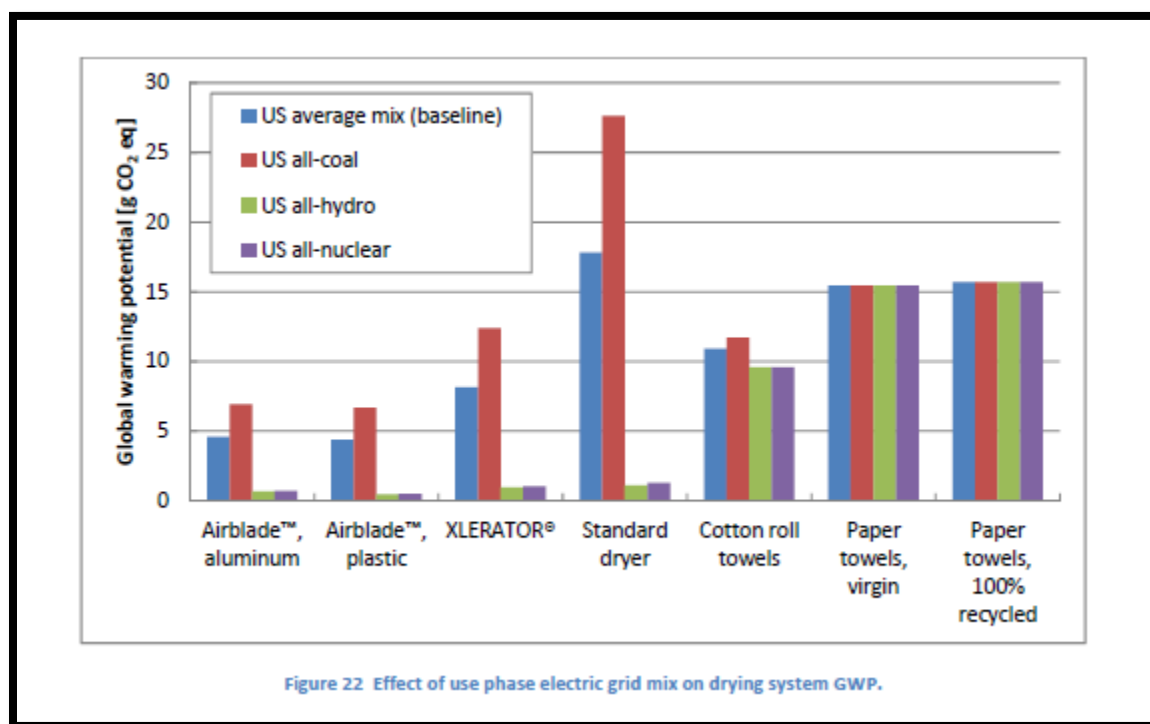


Figure 4 does inspire some hope in regard to the potential efficiencies that EHD's could obtain. If the United States is able to further promote fossil fuel alternatives like hydro, solar and wind energy, the utilization of EHD's in the future seems very promising. Technological

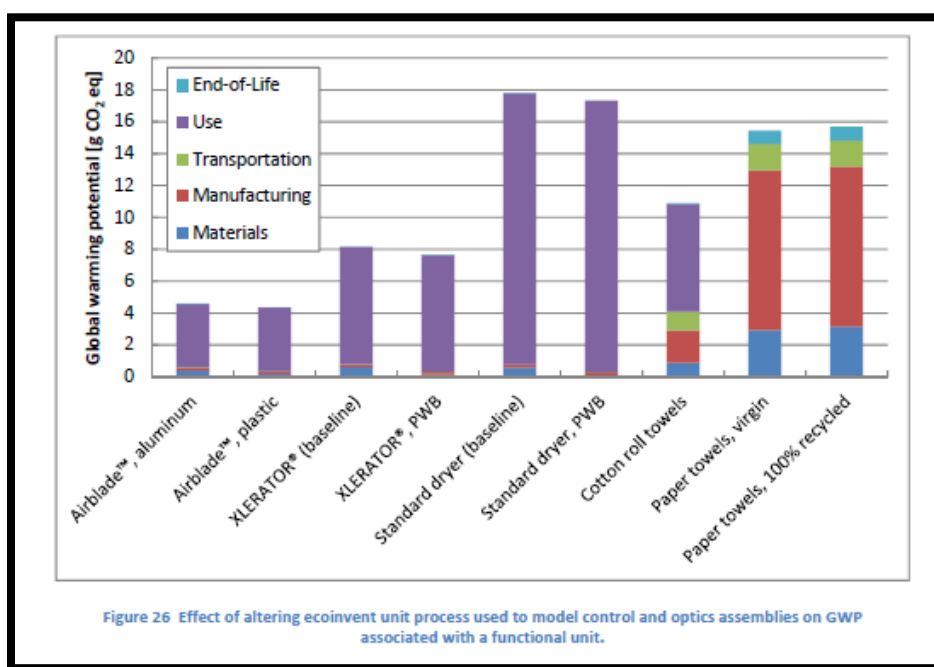


innovation is also very important to consider within this field of study. It is reported that batteries are becoming cheaper by 50 percent per year while continuously increasing efficiency by approximately 8 percent annually (Davies, pp. 5). Battery potential and grid integration remains to be the facet of grid technologies that stakeholders are most optimistic about.

### **Cradle to Grave / Life Cycle Analysis – Waste:**

In order to compare overall efficiencies of the two hand drying methods, EHD's and paper towels, it is important to consider all facets of production, transportation, and materials used. Within Montalbo's study, nine different methodologies were compared via cradle-to-cradle processes. These models consisted of six EHD's, two types of paper towels and one type of cotton roll towels. The criteria used within this C2C analysis were materials used, manufacturing processes, transportation, use (electricity) and end-of-life (landfill). These measurements were all made in terms of global warming potential; CO<sub>2</sub> equivalent.

**Figure 5: Hand Drying Efficiency Assessment - 9 Models (Montalbo, 2011)**



Montalbo's model greatly influenced our methodologies for producing our own C2C analysis on Skidmore College Campus. This analysis in collaboration with MIT (2011) were found to be the most influential throughout this entire experimentation and C2G carbon analysis.

### **Composting – Methane Production:**

A large problem associated with landfills is the production of methane gas, under anaerobic conditions without oxygen methane is approximately 30 times more potent than Carbon Dioxide. This becomes an issue for Skidmore who is landfilling on average about 17,800 lbs. of paper towels each year. In order to determine which hand drying methodology would be more environmentally friendly, we conducted a Carbon Dioxide analysis comparing the schools recent paper towel roles, and the EHD models that we are recommending for the college.

When considering the effects that methane possesses on the environment, we looked to other institutions in the country to see if any have found a resolution in dealing with their methane emissions. This resulted with us encountering Martha Larson, Manager of Campus Energy and Sustainability at Carleton College in Minnesota. She informed us that by increasing centralized waste stations across the academic and administrative buildings, the college was able to expand the availability for composting. This sustainable initiative now allows Carleton to recycle and compost 100 percent of their paper towels. Martha additionally informed us that in order to eliminate methane gas emissions from composting, compost piles have to be heated to at least 131 degrees for 7 days. The compost piles at Carleton are heated to 140 – 160 degrees to ensure the full effect, once the piles reach this stage they are tested for pathogens before use. (Larson, Carleton College, 2017).



### **Post-Consumer Waste:**

In order to compare the overall environmental impact of the current hand drying methodologies at Skidmore, it is important to consider the materials in which they are produced from. The current paper towels that Skidmore using in rest rooms are made up of post-consumer waste materials. PCW is the purest form of recycling, in comparison to standard recycling, post-consumer waste must be used by society and the consumer before being shipped to a recycling facility and being remanufactured into a new material. In comparison, standard recycling can be unjustifiably represented by materials like scraps from a factory floor.

In the last five years Skidmore has been using PCW paper towels in their restrooms across campus. Prior to this year, the college was using 80 percent post-consumer waste paper towels, and has of last year switched to a less environmentally friendly roll of 50 percent post-consumer waste. We found this to be important for our study, because the greater percentage of PCW contents means more economic and environmental benefits. When considering the recent change that Skidmore has made regarding post-consumer paper towels, we will be analyzing the disadvantages of this change and the alternatives that would be more feasible for the college.

### **Geographic Information System (GIS):**

When considering possible locations where electric hand dryers could be implemented in restrooms at Skidmore, we needed to first identify specific locations where they would be feasible in an academic environment. Once we completed our decibel tests across campus, we used a geographic information system to show which areas EHD could be implemented. By using the software, we categorized three areas; very possible integration (green), possible integration (yellow) and could not be integrated (red). Using GIS, we used these colors and highlighted the areas on Skidmore's campus in regards to the possibility of electric hand dryers implementation.

## **Methodologies:**

### **Setting & Population:**

Within this analysis, we would like to investigate the possibilities of reducing paper waste on Skidmore College by installing electric hand dryers. We were particularly motivated to conduct this analysis because Skidmore College is about to build an entire new Center for Integrated Sciences building (CIS). The new 200,000 square foot CIS building will encompass 23 teaching and 46 research labs, 22 instrumentation rooms, 41 project and preparation spaces, five technology suites, 15 classrooms and meeting rooms, as well as social, display, and other public areas. This facility must offer many restrooms in order to adhere to the needs of students and faculty. This demand for newly established restrooms engages our School towards an interesting question; which hand drying methodologies should be installed throughout campus?

### **Economic Analysis:**

When comparing the differences between two hand drying mechanisms, paper towels (PT's) and electric hand dryers (EHD's), economics must be investigated in order to determine the overall potential benefits of a "paper-free" movement. Within our economic analysis, the total costs of paper towels were compiled over a five-year span and averaged. This average annual expense was equivalent to \$26950. We did not additionally include any charges for trash delivery because we discovered that the landfill which Skidmore College Dumps at is less than 15 miles away. The exact location of the dump site is called Finch Paper Landfill and is Located exactly at 19 Peters Rd. Gansevoort, NY (Kellogg, 2017).

We compared the yearly average cost of the paper towels to the cost of the Xlerator electric hand dryers plus their electrical use. We estimated that if Skidmore purchased a bulk shipment of electric hand dryers, they would realistically cost \$400 each. For the 82 total models, this amounted to a grand total inputs cost of \$32,800. We assumed that Skidmore facilities staff is capable of installing the hand dryers. Since Skidmore facilities' employees receive an annual salary, the cost of installation can be assumed to not increase. We then calculated the total electric use that the 82 hand dryers would use in relation to the total paper towel utilization on Skidmore Campus. We were able to determine the electrical use of the Xlerator hand dryer via their website and model blueprints. This informed us that 1381 total kilowatt hours of energy are consumed throughout the entire lifecycle of the hand dryer which amounts to 260,000 uses. With these estimates, we were able to calculate the total electrical use of our three associative models; the conservative (2,347,800 uses), the normative (1,760,850), and aggressive (1,173,900) model. Each of these relatively represents 1.5, 2, and 2.5 paper towels used instead of one Xlerator dry cycle and were calculated to utilize 12470.43, 9352.82, and 6235.21 kilowatts hours of electricity accordingly. In relative economic terms; Skidmore pays .0505 cents per kWh. In total we

estimated that our normative model would amount to \$472.32 for the 9352.82 kWh's of electricity used.

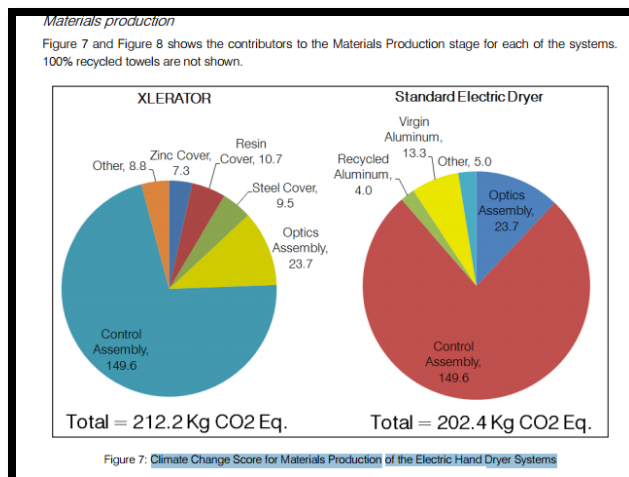
### **Paper Towel - C2G: (Cradle-To-Grave)**

Within our cradle to grave analysis of paper towels, we include the carbon emission equivalencies of the paper production and methane emissions produced within landfills. Even though a typical C2G analysis includes the production, utilization, transportation, and removal materials input costs; our analysis does not incorporate transportation costs because we are assuming that Skidmore cannot realistically end their routine trash pickups. Within our investigation, we utilize the EPA paper equivalency calculator to identify all material inputs required throughout the entire production process. Within this analysis all of the technical and biological inputs and the entirety of environmental effects caused by the product's utilization are analyzed throughout these calculations.

### **Electric Hand Dryer - C2G:**

Within our C2G analysis of the Xlerator electric hand dryer, we were able to utilize Xlerator's previously calculated carbon equivalency for the overall materials production stage for each of the individual systems that make up the dryer. These systems are the control assembly, optics assembly, steel cover assembly, resin cover assembly, zinc cover assembly in order of greatest to least CO<sub>2</sub> equivalence. These associative values can be expressed within figure (6).

**Figure (6):** Environmental Impact of Materials Production of Xlerator and Standard Electric Hand Dryer (Xlerator, 2017).



### Noise Pollution and Decibel Analysis :

Noise pollution is an extremely important issue to consider specifically when conducting a bathroom sanitation analysis within an academic institution. Our investigation both encompasses an analysis of noise pollution caused by the electric hand dryer's as well as the conditions and materials which construct of the restroom's surfaces. We expected that the materials such as plaster, wood overlay, insulation, brick, metal ect., will all have different reactions towards the sound created by electric hand dryers. We also believe that the materials and thickness of the restrooms door is an important factor to consider with in our decibel reading detection. These are the overall conditions of the restrooms that we will be investigating and recording throughout our research.

In order to determine the noise pollution caused by the electric hand dryer's, we attempted to replicate the volume of the Xlerator electric hand dryer. We attempted to do this by utilizing a *Digital Sound Level* decibel reader that we were able to purchase with student opportunity funds. This decibel reader was donated after completion of our experimentation process in order for future capstones to additionally work on this project. We utilized the Excel Dryer Inc.'s exact decibel specifications in order replicate the volume with our speakers. These

specifications were operating at 78-80 dB $\pm$ . This sound level was measured in front of the *dryer/speaker* at a height of 5 feet (152 cm) from the floor and 18 inches (46cm) from the wall (Xlerator Inc., 2017). We specifically selected the most likely place of integration, to our best ability, and analyzed this volume from outside the restroom as well as within the most local classroom or offices.

### **Surveys - Qualtrics Data:**

We distributed surveys online via Qualtrics. One purpose of this investigation was to identify people's overall opinions towards paper towels and the utilization of Electric hand dryers. This topic must be addressed because it directly reveals how easily people's behaviors could change. Our survey sample size was 110 and included the following questions.

## **SURVEY DATA QUESTIONS**

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- 1. Are you a Skidmore College Student OR currently employed by Skidmore College?**
- 2. If you walked into a restroom and saw an Electric Hand Dryer & Paper Towel dispenser, which method would you choose for drying your hands?**
  - Paper Towels, Electric Hand Dryer, Neither-don't dry, Neither-don't wash, indif.
- 3. React to the following statement: "I use paper towels to open the door when leaving the restroom"**
  - Strongly Agree, Disagree, I do not know, Agree, Strongly Agree.



**4. If any, which problems do you associate with electric hand dryers? Choose all that apply.**

- Volume-too noisy, dry duration too long, do not work properly, spread germs, n/a.

**5. Which problems would do you associate with the utilization of paper towels within restrooms?**

- Too wasteful, cause deforestation, unsustainable, spread germs, use too many.

**6. React to this statement "If electric hand dryers were statistically proven to be more economically feasible and environmentally friendly for Skidmore College, I would support an initiative to install electric hand dryers throughout campus and change my behavior?"**

- Strongly Agree, Disagree, I do not know, Agree, Strongly Agree.

**7. Try to guess: How many rolls of paper towels per year does Skidmore College use.**

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### **Composting:**

We additionally created and conducted a composting experiment on campus in order to determine how compostable paper towels actually are. We also wanted to determine the comparative differences in composting efficiencies in regard to the two different types of paper towels that Skidmore has been using throughout the past five years. These two rolls are created out of 80% and 50% post-consumer waste and are also 100% recycled (Skidmore Facilities Report, 2017).

Within the assistance of the Skidmore Composting team, we inserted one pound of each type of paper towel individually into Skidmore's on-campus composting site located behind the

Northwood's Parking Lot. We planned on investigating the composting process throughout the span of approximately two months.

### **Local Investigation / Stakeholder Analysis:**

We also explored the local surrounding restaurants, shopping centers, and bars in order to locate an ideal model to replicate within Skidmore College. Throughout this investigation, we were able to determine that the newly constructed Burgerfi restaurant on Broadway perfectly constructed their restroom to our specifications. They utilize only the Xlerator hand dryer and do not use paper towels. We have determined this location to be the Gold standard for replication at Skidmore College.

### **Methods Triangulation + Data Triangulation:**

We will be utilizing data triangulation within our capstone study in order to provide corroborating evidence. In order to properly utilize this methodology, we must make use of multiple and different sources, methods, investigators, and theories to create the most statistically relevant data set (Creswell, pp. 151). Creswell acknowledges that data triangulation functions as a validation strategy for data collection. This is why this form of methodology was chosen for our capstone project.

### **Limitations:**

One of the largest limitations to this study is regarding that this project would require a lot of labor to entire integrate electric hand dryers on campus. This would require vast amounts of additional work from the Skidmore Facilities Crew and Skidmore Composting Team. Another limitation of this study is that we were not able to analyze the comparative sanitary efficiencies. Since neither micro-biologists, we deemed this form of analysis beyond the scope of our analysis. Instead of conducting a bacterial experiment, we utilized our best judgement aligned

with the literature in order to conclude that electric hand dryers are expected to only detrimental to the user's hygiene if the bathrooms are very dirty and this air is being further circulated. Since our restrooms on Skidmore Campus are generally cleaned daily; we do not believe there would be any issues with integrating electric hand dryers on campus. Another general limitation that we approached with multiple times was biological hygiene data. Since neither of us are have any knowledge on bacterial colonization, we deemed a bacterial experiment beyond the scope of our study.


## **Results - Economic Analysis:**

**Figure 7:** Skidmore College Expense Data



We were able to find out that Skidmore College has been paying nearly \$27,000 every single year on paper towels. To our surprise, Skidmore College has recently started to pay more money for a less environmentally friendly roll of paper towels. The newer roll of paper towels that has been purchased from 2016 onwards is only comprised of 50% post consumer waste. The newest model's cost is circled in red within figure 7. In comparison, the previous roll that Skidmore had been using is comprised of 80% post consumer waste. We then utilized this average valuation of \$26,950 to comparatively analyze the economics of the paper towels that we are currently using and the Xlerator electric hand dryer.

**Figure 8:** Electric Hand Dryer Economic Analysis



## ECONOMIC ANALYSIS

<b>XLERATOR USE MODEL</b>	<b>Total Uses</b>	<b>Cost of 82 Devices</b>	<b>Annual Energy Consumption (kWh)</b>	<b>Skidmore's Electricity Costs per kWh(¢/\$)</b>	<b>Annual Total Cost (Dollars - \$)</b>
<b>Conservative (1.5T)</b>	2,347,800	82 * \$400 = \$32,800	12470.43	\$0.05	\$629.76
<b>Normative (2T)</b>	1,760,850	82 * \$400 = \$32,800	9352.82	\$0.05	\$472.32
<b>Aggressive (2.5T)</b>	1,173,900	82 * \$400 = \$32,800	6235.21	\$0.05	\$314.88

Within this analysis, three expectation models are used in order to comparatively analyze the amount the total amount of paper towels used on campus to one Xlerator electric hand dryer cycle. We were also able to determine that Skidmore is currently paying 0.0515 cents per kWh. We found the total amount of paper towels used per year on campus equivalent by calculating the average amount of rolls used per year. This average amount equates to a sum of just over 3.5 million paper towels used per year. We multiply this cost by the total amount of expected kWh's used within the associative expectation model. The first model was the conservative paper towel utilization estimate. This expectation model associated one Xlerator hand dryer use to 1.5 paper towels used within Skidmore's restrooms. This would equivilate to just over 2.3 million cycles of the Xlerator hand dryer and would therefore utilize just over 12,000 kWh's of electricity. This expectation model would estimate that Skidmore would only spend \$629.76 in our very most conservative model if Skidmore utilized Xlerator electric hand dryers instead of cascades paper

towels. Within our normative model, we equated each Xlerator electric hand dryer to 2 paper towels used within Skidmore's Restroom. We were able to determine with this model that the Xlerator hand dryers would utilize just over 9000 kWh's of electricity and would cost the college just under \$475. The third model was the aggressive paper towel utilization estimate. This expectation model associated one Xlerator hand dryer use to 2.5 paper towels used within Skidmore's restrooms. This would equate to just over 1.1 million cycles of the Xlerator hand dryer and would therefore utilize just over 6000 kWh's of electricity.

**Figure 9:** Skidmore College 10 Year Savings Projection

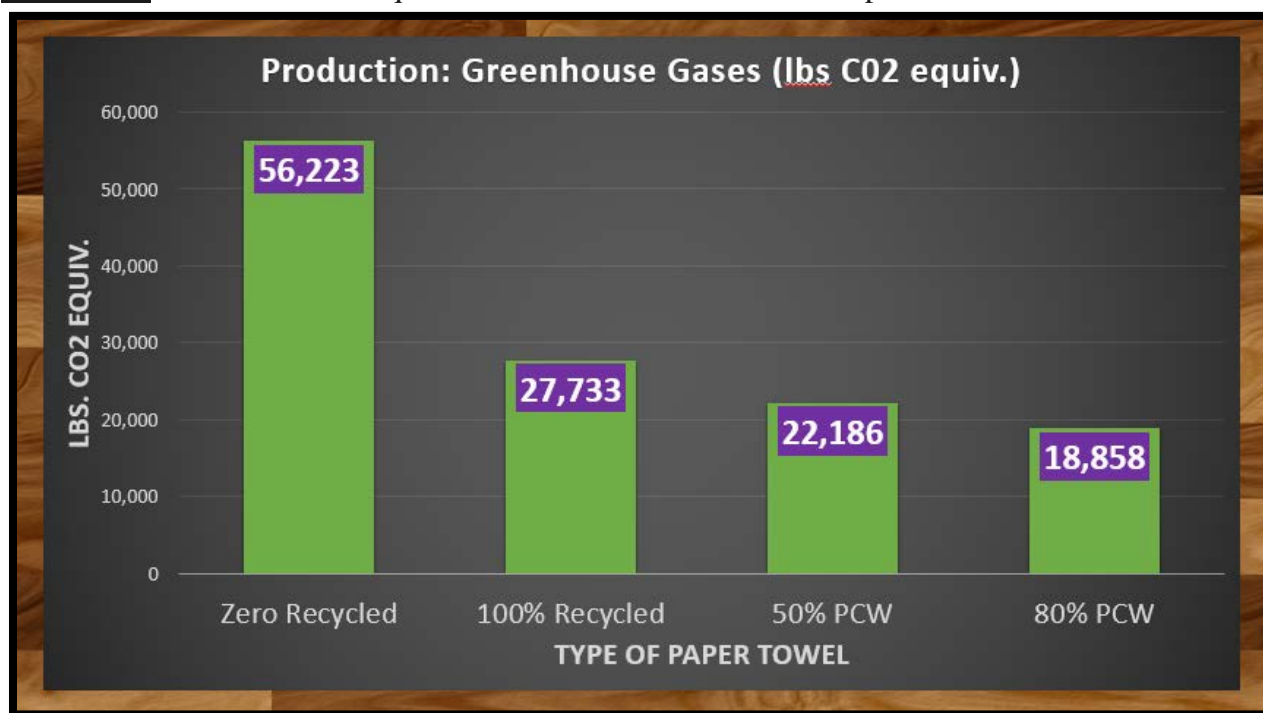


Within figure 9, our estimation of Skidmore College's 10 savings on a ten year associative projection are show to be valued just below a quarter million dollars. Additionally, we calculated that the cost of one Xlerator electric hand dryer would cost about \$400 if we were able to make the purchase in bulk. In total we calculated that the total 82 electric hand dryers that

we want to install on campus would cost just under \$32,000. We did not include any installation costs because we assumed that Skidmore College facilities team is capable of installing the Xlerator dryers. It is also important to recognize that Skidmore is currently receiving a great rate in regard to their price paid per kWh. This low price of 0.0515 cents per kWh is paid and has been valued throughout previously power purchasing agreements made by Skidmore College.

### **Results - Carbon Audit Analysis:**

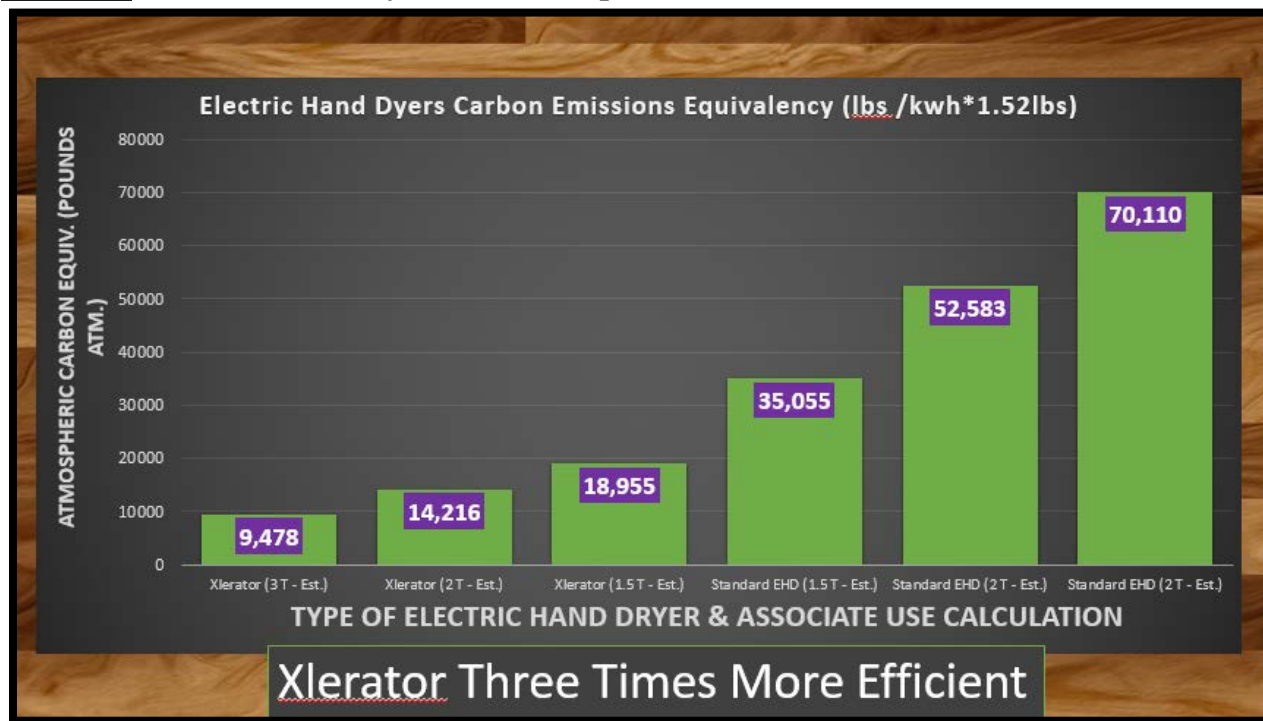
**Figure 10:** Production CO2 Equivalencies of Different Kinds of Paper Towels



We utilized the Environmental Paper Network's paper calculator in association with Skidmore College's 17,800 total pounds of paper waste per year. Before continuing, we calculated the total physical waste that the paper towels produce when dry and freshly packaged. We took the average of weights of the two rolls that Skidmore College has been using over the past five years and multiplied it by the averaged amount of rolls used per year. The average amount of rolls used per year is also an averaged amount due to the fact that the previous roll

that we used consisted of only 750 sheets and the newer roll now consist of 1050 sheets. We believe that this switch to the less environmentally friendly roll within 2016 (Figure 7) was made primarily because the newer roll has more sheets and therefore must be replaced less often.

**Figure 11: Electric Hand Dryer Model Comparison - Xlerator vs. Standard Model**






Within figure 11, it is shown that on every form of the Xlerator expectation model was vastly more efficient than the standard electric hand dryer in comparison. The Xlerator estimates are the three furthest to the left and are shown to be more than three times as efficient. We created these calculations by analyzing the comparative lifecycle estimates of Xlerator versus the standard conventional electric hand dryer. We were able to discover that the Xlerator on average will utilize 1381 kWh's for every 260,000 dry cycles. In comparison the conventional dryer would use 5108 kWh's for every 260,000 dry cycles (Figure 12).

**Figure 12: Electric Hand Dryer Lifecycle Calculations. (Xlerator, 2017).**



Table 1: Key Characteristics of the Products Studied (baseline scenarios)

	 <b>XLERATOR Hand Dryer</b>	 <b>Conventional Hand Dryer</b>	 <b>Paper Towels</b>
<b>Functional Unit</b>	Drying 260,000 Pairs of hands		
<b>Product needed for Functional Unit</b>	One dryer and 1381 kWh electricity	One dryer and 5108 kWh electricity	One dispenser plus 37,960 m <sup>2</sup> of paper towel
<b>Housing Components</b>	Zinc, stainless steel or reinforced resin (even combination of 3 optional covers)	Zinc and aluminum	Polypropylene
<b>Internal components</b>	Motor, fan, optical sensor, wiring	Motor, fan, optical sensor, wiring	Motor, optical sensor, batteries
<b>Manufacturing Location</b>	East Longmeadow, Massachusetts, USA	USA	USA
<b>Distribution</b>	Shipped as single units or on pallets to distributor	Shipped as single units or on pallets to distributor	Shipped as single units or on pallets to distributor.
<b>Supply Chain Distances</b>	750 km by truck and 750 km by ship for all components	750 km by truck and 750 km by ship for all components	750 km by truck and 750 km by ship for all components
<b>Packaging Material</b>	Plastic liner bag within corrugated cardboard box, with molded pulp end caps	Plastic liner bag within corrugated cardboard box, with molded pulp end caps	Dispenser in plastic liner bag within corrugated cardboard box, with molded pulp end caps; towels in corrugated cardboard box.
<b>Recycling Rate</b>	Packaging recycled at national material averages (U.S. EPA 2007); dryer components not recycled	Packaging recycled at national material averages (U.S. EPA 2007); dryer components not recycled	Packaging recycled at national material averages (U.S. EPA 2007); dispenser components not recycled; towels not recycled
<b>Use Phase Assumptions</b>	12 second run time with 1500 watts of electricity draw (plus 1.5 second shutdown at half power)	30 second run time with 2300 watts of electricity draw (plus 1.5 second shutdown at half power)	2 towels used, with 0.073 m <sup>2</sup> area per towel.

**Figure 13:** Conservative, Normative, and Aggressive EHD use Calculations

<b>ELECTRIC HAND DRYERS</b>				
	<b>XLERATOR (Joules)</b>	<b>XLERATOR (kWh)</b>	<b>STANDARD MODEL (Joules)</b>	<b>STANDARD MODEL (kWh)</b>
<b>Conservative</b>	44893547996.39	12470.43	166050864009.03	46125.24
<b>Normative</b>	33670160997.29	9352.82	124538148006.77	34593.93
<b>Aggressive</b>	22446773998.19	6235.21	83025432004.52	23062.62

Within figure 13, our total electricity calculations are shown. Throughout our three models, we calculate the associative electrical use of the amount of dry cycles would utilize. This calculation originally had to be completed in joules and then converted back into kWh's. These calculated kWh's could then be multiplied by the total carbon dioxide emissions estimations rated produced by the Environmental Protection Agency (EPA). Using the EPA's calculations as a reference, we were able to determine that one kilowatt hour used produces approximately 1.52 pounds of carbon dioxide within the atmosphere. These estimations are excluding line losses within their calculations (EPA, 2017).

We were additionally concerned about the total methane that was being produced after Skidmore college landfilled 17,800 pounds of paper waste. In order to create these calculations we needed to learn that there is a difference in methane produced if the waste is either dry or wet. For simplicity sake, we utilized the average sum of wet and dry paper methane production equivalencies within this analysis. These relative equivalencies can all be observed within figure 14. Within our calculation estimations, we were forced to use the relative methane production calculations for newspapers within our analysis. This was because the EPA did not provide exact calculations for paper towels. We believe that this would be an interesting question to analyze in the future as more landfill methane emission studies are conducted.

**Figure 14:** Comparative Methane Produced between Dry and Wet Paper Materials reported in relative tons of Atmospheric CO<sub>2</sub> Equivalence (EPA, 2015).

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**Exhibit 6: CH<sub>4</sub> Yield for Solid Waste Components**

Material/Product	Initial Biogenic Carbon Content	Adjusted Yield of CH <sub>4</sub> as Proportion Of Initial Carbon	Final (Adjusted) CH <sub>4</sub> Generation, MTCO <sub>2</sub> -E/Dry Metric Ton <sup>a</sup>	Final (Adjusted) CH <sub>4</sub> Generation (MTCO <sub>2</sub> -E / Wet Short Ton) <sup>b</sup>
Corrugated Containers	47%	22%	3.48	2.62
Magazines/Third-Class Mail	33%	28%	3.11	2.59
Newspaper	49%	8%	1.33	1.05
Office Paper	32%	44%	4.71	3.89
Phone Books	49%	8%	1.33	1.05
Textbooks	32%	44%	4.71	3.89
Dimensional Lumber	49%	1%	0.24	0.17
Medium-Density Fiberboard	44%	1%	0.08	0.06
Food Waste	51%	42%	7.13	1.75
Yard Trimmings				
Grass	45%	23%	3.48	0.57
Leaves	46%	8%	1.17	0.65
Branches	49%	7%	1.12	0.85
Mixed MSW	42%	16%	2.23	1.62
Drywall	5%	0%	0	0
Wood Flooring	46%	2%	0.35	0.24

<sup>a</sup> Final adjusted CH<sub>4</sub> generation per dry metric ton is the product of the initial carbon content and the final percent carbon emitted as CH<sub>4</sub> multiplied by the molecular ratio of carbon to CH<sub>4</sub> (12/16).

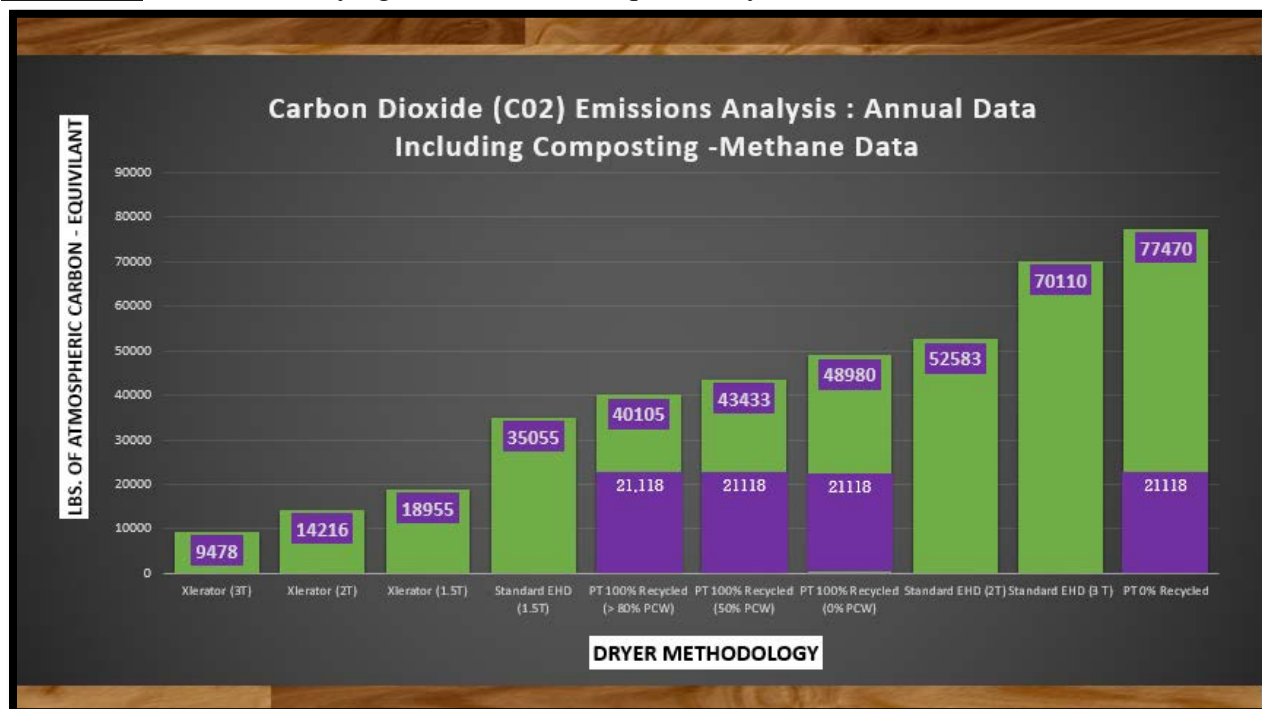
<sup>b</sup> CH<sub>4</sub> generation is converted from per dry metric ton to per wet short ton by multiplying the CH<sub>4</sub> generation on a dry metric ton basis by (1 – the material's moisture content) and by converting from metric tons to short tons of material.

Within figure 14, it the relative methane productions are shown for dry and wet materials in regard to their total CO<sub>2</sub> emissions equivalencies. Within figure 15 below, our calculations are shown to equate to emitting 2,380 pounds of carbon dioxide in the atmosphere for every ton of paper placed into the landfill. For the total 17,800 pounds of paper that Skidmore college places into a landfill every year, we have calculated that this equates to the same as emitting 21,182 pounds of carbon into the atmosphere.

**Figure 15:** Calculated CO<sub>2</sub> Equivalence to the Methane Produced in Landfills (EPA, 2015).

Findings - Landfills & Methane Production	
2000 lbs. of Paper Towels = Methane Equivalent	→ 2,380 (lbs.CO <sub>2</sub> E)
17,800 lbs. of Paper Towels = Methane Equivalent	→ 21,182 (lbs.CO <sub>2</sub> E)

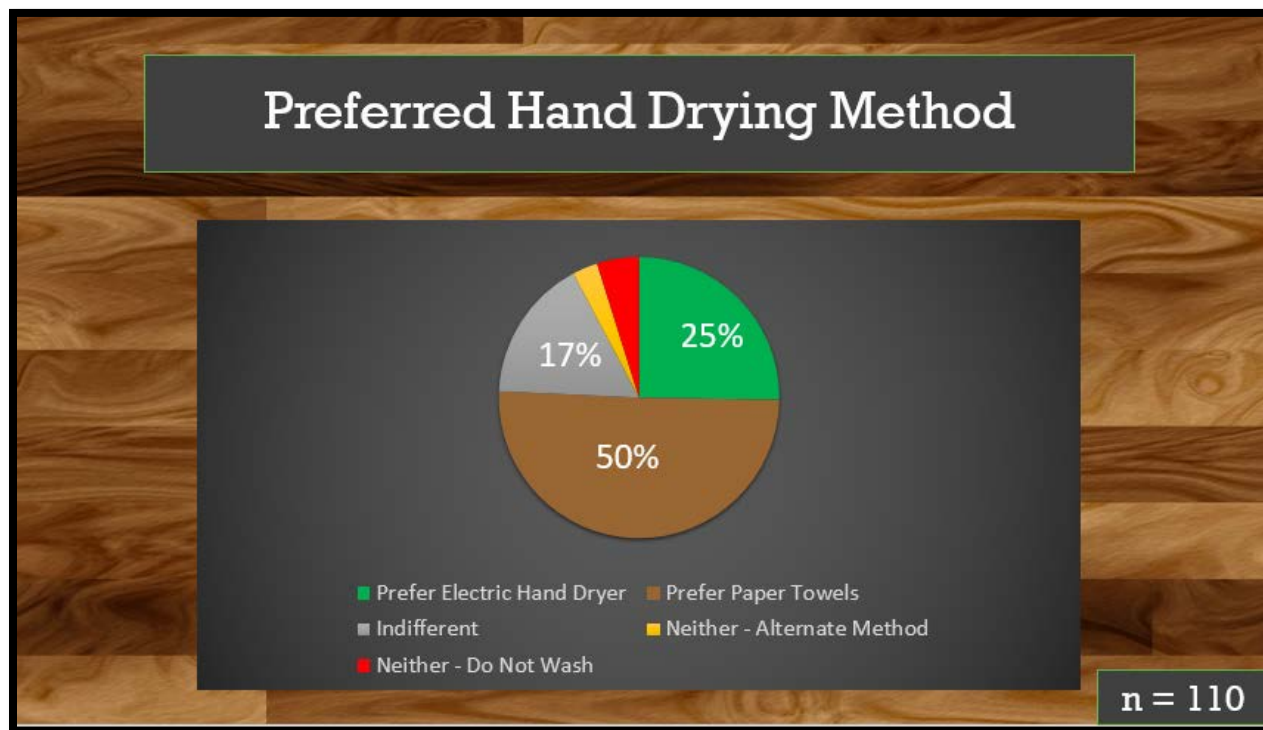
**Figure 16:** Total Hand Drying C02 Emissions Equivalency Calculations



We express our carbon audit calculations in final form within figure 16. This includes every analyzed for of hand drying methodology's carbon emission equivalencies that would be created in one year. To conclude, we were able to determine that the less environmentally friendly roll that Skidmore College is now using was estimated to create more than 3000 additional pounds of carbon emissions per year in comparison to the schools previously utilized roll from 2012-2015. Additionally we were able to conclude that the Xlerator on the most conservative expectation model was proven to be more than four times as environmentally friendly in comparison to the most environmentally efficient roll which we are no longer using.

## Results - Survey Analysis:

**Figure 17:** Skidmore College Hand Drying Preference Survey

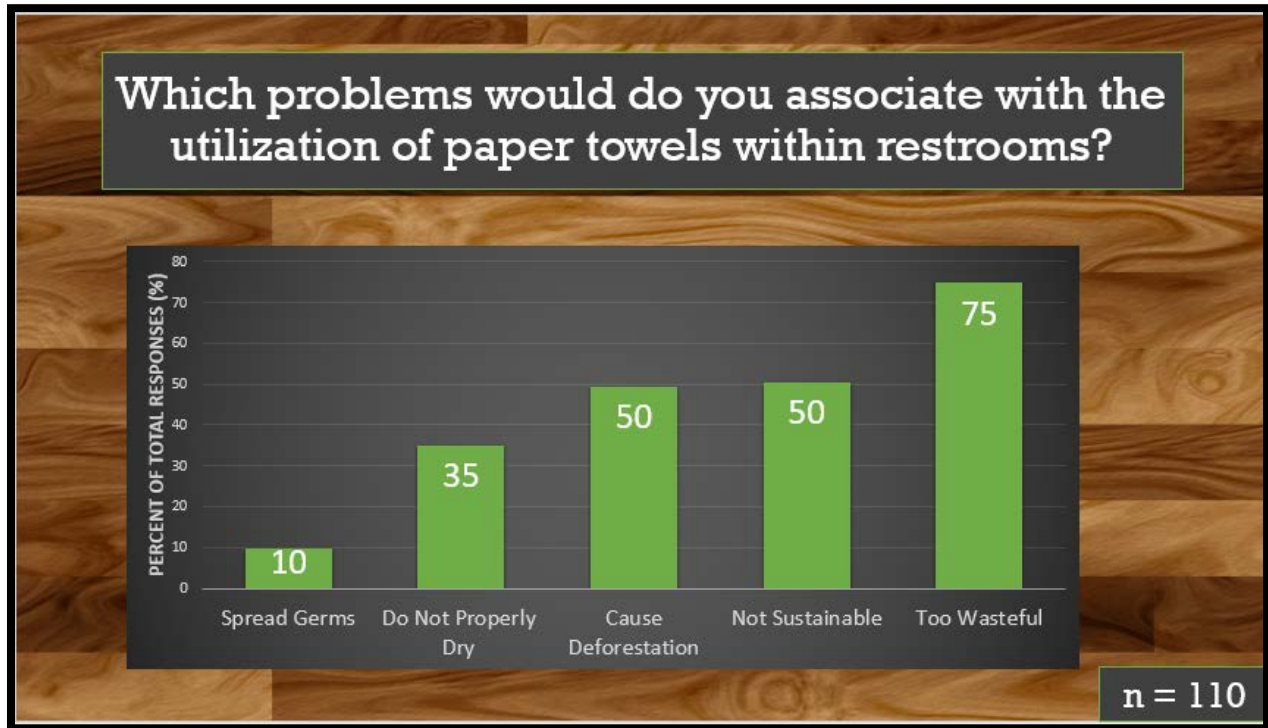


**Figure 18:** Associated Problems with Electric Hand Dryers - Student Perceptions

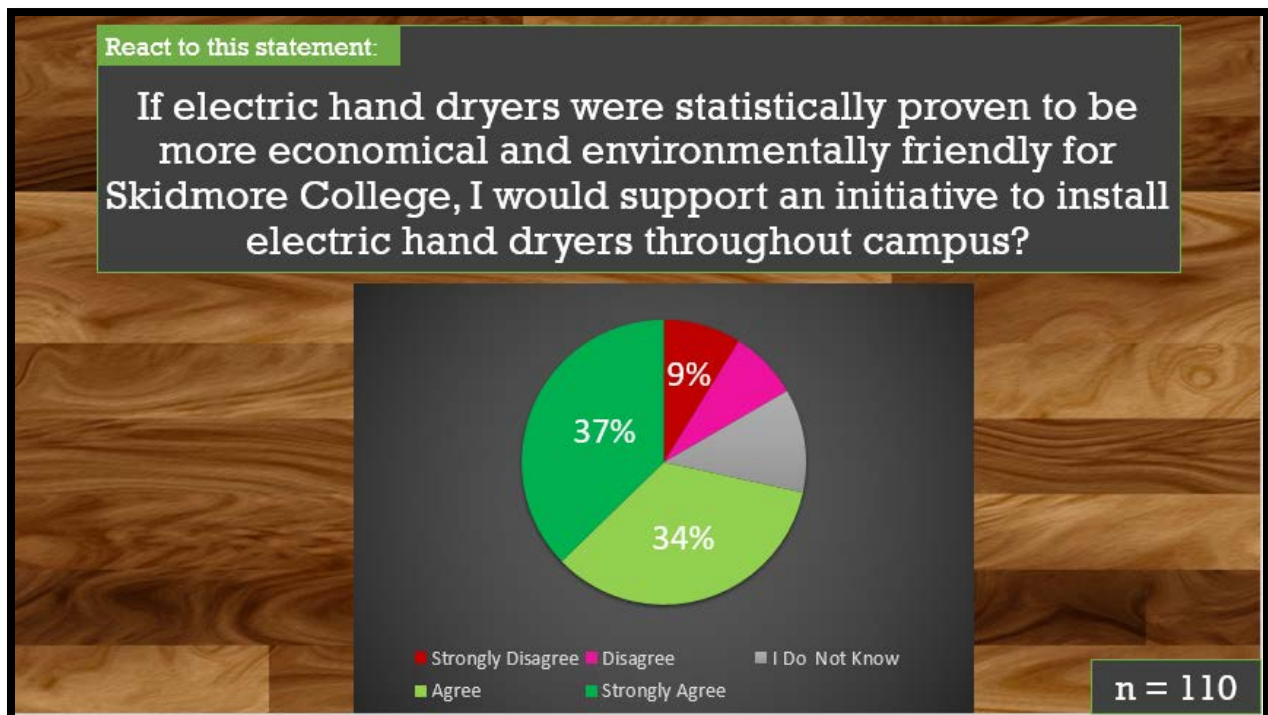




**Figure 19:** Associated Problems with Paper Towels - Student Perceptions



**Figure 20:** Willingness to Change Behavior - Thesis Question



Our survey results are shown graphically above throughout figures 17-20. Figure 17 first portrays the overall preference of Skidmore students regarding hand drying methodologies. This graph shows that exactly half of the respondents told us that they prefer to use paper towels more than any other methodology if given the option. Figure 18 shows what Skidmore Students believe to perceive as the largest problems associated with electric hand dryers. The results of this question showed that Skidmore Students found electric hand dryers take too long to dry hands, are too noisy, and do not properly dry hands to be the most concerning issues. Figure 19 discusses the problems that Skidmore College students associate with paper towel utilization. Skidmore students found that fact that paper towels were too wasteful, not sustainable, and cause deforestation to be the most impacting problems associated with their use. Finally, figure 20 expresses our overall thesis question which states "if we can convince you that electric hand dryers are both more environmentally friendly and economically feasible on Skidmore College campus, would you be willing to support our initiative to install these devices and change your behaviors". Shockingly, 71% of the students that took our survey stated that they either agree or strongly agree with our thesis statement. This concluding statistic is very important to recognize because the exact same population of Skidmore College students cited that they prefer to use paper towels in figure 17.

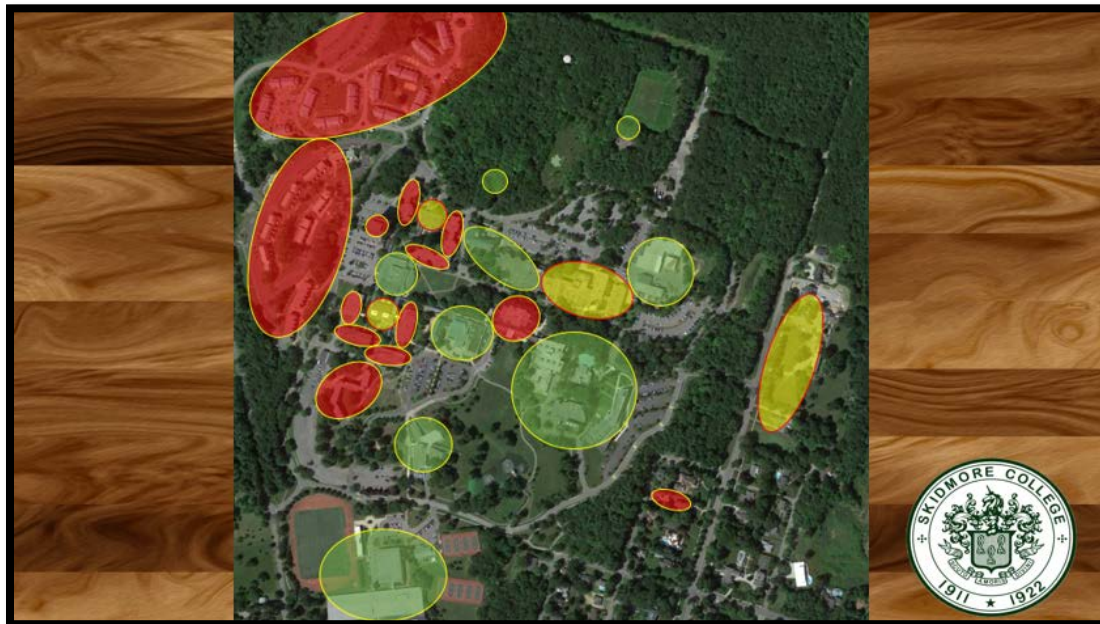
## **Results - Decibel Testing Analysis:**

**Figure 21:** Electric Hand Dryer Integration Potential Experiment Procedures



Within our electric hand dryer integration potential experiment, we went into the vast majority of restrooms on Skidmore College Campus in order to determine which bathrooms were could feasibly have electric hand dryers installed within them within any major repercussions. This experiment was particularly necessary to conduct within our analysis because the second largest concern of our Skidmore Student body sample survey was that these devices were too noisy. In figure 22, the 82 locations on campus we found feasible are graphically represented.

**Figure 22:** Graphical Representation of EHD Integration Potential








### **Results - On Campus Composting Experiment:**

Our on campus composting experiment was found to be very successful. After inserting one pound of each type of paper towel roll that Skidmore College has been using over the past 5 years, we expected that this overall composting process would take at least one month. To our surprise, each type of paper towel was entirely gone after just two weeks. One major concern when composting used paper towels is the fact that E.coli, fecal matter, and other bacteria's can be growing throughout the decomposition process. We were able to determine that the composting pile must be at least 131 degrees hot for 7 days to entirely eliminate the harmful bacteria's that could be potentially produced. We were able to find this out from Carleton college whom utilizes a third party composting facility to recycling 100% of their used paper towels.

## **Results - Concluding Remarks - Final Recommendations:**

**Figure 23:** Best Case, Next Best Case, and Current Scenarios - Suggestions for the Future

<b><u>Best Case Scenario</u></b>	<b><u>Next- Best Case Scenario</u></b>	<b><u>(CURRENT)</u></b>
<ul style="list-style-type: none"> <li>• Switch entirely to Electric Hand Dryers where possible (82 Locations)</li> <li>• *Ideally Create No Paper Waste.</li> </ul>	<ul style="list-style-type: none"> <li>• Integrate EHD's where possible.</li> <li>• Switch back to 80% PCW paper towels on Campus.</li> <li>• Compost any additional paper waste produced to eliminate Methane Emissions.</li> </ul>	<ul style="list-style-type: none"> <li>• Do not integrate EHD's on Skidmore College.</li> <li>• Continue using 50% PCW paper towels on campus.</li> <li>• Do not compost paper towels - create methane emissions.</li> </ul>
<div>  <p>Goal 1: 60% diversion rate in routine operations - Currently 27% diversion rate in routine operations</p> <p>Goal 2: 50% diversion rate for special projects</p> </div> <div>  </div> <div>  </div>		

Regarding the future of the utilized hand drying methodology utilized on Skidmore College Campus, we believe that the best case scenario would be to entirely switch out every single paper towel dispenser on campus and replace them with Xlerator electric hand dryers. We understand that this suggestion is not entirely realistic due to the currently existent infrastructure in place. For this reason, we suggest that the next best case scenario would be to work with the Skidmore College Sustainability Department to install electric hand dryers wherever possible. Additionally, if we have to continue to utilize paper towels on campus, we recommend that Skidmore College reverts back to the previously purchased and more environmentally friendly type of roll. Finally, we recommend that Skidmore college further investigates the potential environmental benefits of composting the paper towel waste on campus. We believe that all of these previously listed initiatives would significantly benefit Skidmore's 2020 Sustainability Goal which is geared at reducing on campus waste by 60% in the next 3 years.

## References

1. Best, E. (2015). *Comparison of different hand-drying methods: the potential for airborne microbe dispersal and contamination*. Journal of Hospital Infection. Vol. 89. Iss. 3. Pp. 215-217. Retrieved from:  
<http://www.sciencedirect.com/science/article/pii/S0195670114003727>
2. Best, E. et al. (2014). *Microbiological comparison of hand-drying methods: the potential for contamination of the environment, user, and bystander*. Journal of Hospital Infection. Vol. 88. Iss. 4. Pp. 199-206. Retrieved from:  
<http://www.sciencedirect.com/science/article/pii/S0195670114002461>
3. Berkowitz, S. (2015). *Hand dryer noise in public restrooms exceeds 80 dBA at 10 ft (3 m)*. Noise & Health, A bimonthly Interdisciplinary International Journal. Vol. 17. Iss. 75. Pp. 90-92. Retrieved from: [http://www.noiseandhealth.org/article.asp?issn=1463-1741%3Byear%3D2015%3Bvolume%3D17%3Bissue%3D75%3Bspage%3D90%3Bepage%3D92%3Baulast%3DBerkowitz&hc\\_location=ufi](http://www.noiseandhealth.org/article.asp?issn=1463-1741%3Byear%3D2015%3Bvolume%3D17%3Bissue%3D75%3Bspage%3D90%3Bepage%3D92%3Baulast%3DBerkowitz&hc_location=ufi)
4. Creswell, J. (2013). Qualitative Inquiry & Research Design. Choosing Among Five Approaches. Triangulation Information – Methodologies. Pp. 251.
5. Dawson, P. Et al. (2016). *Bioaerosol Formation and Bacterial Transfer from Commercial Automatic Hand Dryers*. Journal of Food: Microbiology, Safety & Hygiene. Vol. 1. Iss. 2. Retrieved from:
6. <http://www.omicsonline.org/open-access/bioaerosol-formation-and-bacterial-transfer-from-commercial-automatichand-dryers-.pdf>
7. Xlerator (2017). Xlerator Hand Drying Electricity Use and Lifecycle - Comparison to the conventional electric hand dryer. Retrieved from:  
<http://www.exceldryer.com/pdfs/LCAFinal9-091.pdf>
8. EPA (2017). Carbon Equivalency Calculation of One Kilowatt hour used being 1.52 pounds. <https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references>
9. EPA (2015). Methane Production of Landfilled Paper Products. Image. Retrieved from:  
<https://www3.epa.gov/epawaste/conserve/tools/warm/pdfs/Landfilling.pdf>
10. Gregory, Jeremy. Et al. (2013). *Analyzing uncertainty in a comparative life cycle assessment of hand drying systems*. The International Journal of Life Cycle Assessment. Vol. 18. Iss. 8. Pp. 1605-1617. Retrieved from:  
<http://link.springer.com/article/10.1007/s11367-013-0606-0>

11. Gustafson R. Daniel. (2000). *Effects of 4 Hand-Drying Methods for Removing Bacteria From Washed Hands: A Randomized Trial*. Mayo Clinic Proceedings. Volume 75. Iss. 7. Pp. 705-708. Retrieved from:  
<http://www.sciencedirect.com/science/article/pii/S002561961164617X>
12. Harrison A. Wendy. (2003). *Bacterial transfer and cross-contamination potential associated with paper-towel dispensing*. American Journal of Infection Control. Vol. 31. Iss. 7. pp. 387-391. Retrieved  
from:<http://www.sciencedirect.com/science/article/pii/S0196655303000798>
13. Huang, Cunrui (2012). The hygienic Efficacy of different Hand Drying Methods: A review of Evidence. Retrieved from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3538484/#bib39>
14. Ingwersen, Wesley. Et al. (2016). *Detailed life cycle assessment of Bounty® paper towel operations in the United States*. Journal of Cleaner Production. Vol. 131. Pp. 509-522. Retrieved from: <http://www.sciencedirect.com/science/article/pii/S0959652616304383>
15. Jensen, Dane. Et al. (2015). *Quantifying the Effect of Hand Wash Duration, Soap Use, Ground Beef Debris, and Drying Methods on the Removal of Enterobacter aerogenes on Hands*. Journal of Food Protection. No. 4. Pp. 636-858. Retrieved from:  
<http://www.ingentaconnect.com/content/iafp/jfp/2015/00000078/00000004/art00007>
16. Joseph, Tijo. (2015). *A comparative life cycle assessment of conventional hand dryer and roll paper towel as hand drying methods*. Journal of Science of The Total Environment. Vol. 515-516. Pp. 109-117. Retrieved from:  
<http://www.sciencedirect.com/science/article/pii/S0048969715001424>
17. Kellogg, Karen (2017). Electricity Costs of Skidmore College. Skidmore College.
18. Kimmitt, P. (2016). *Evaluation of the potential for virus dispersal during hand drying: a comparison of three methods*. Journal of Applied Microbiology. Vol. 120. Iss. 2. Pp. 478-486. Retrieved from: <http://onlinelibrary.wiley.com/doi/10.1111/jam.13014/full>
19. Margas. E. Et al. (2013). *Assessment of the environmental microbiological cross contamination following hand drying with paper hand towels or an air blade dryer*. Journal of Applied Microbiology. Vol. 115. Iss. 2. Pp. 572-582. Retrieved from:  
<http://onlinelibrary.wiley.com/doi/10.1111/jam.12248/full>
20. Marra, Madison. (2014). *Paper Towel Use and the Installment of Hand Dryers at Colby*. Colby College Journal Catalogue. Retrieved from:  
<http://digitalcommons.colby.edu/clas/2014/program/316/>
21. Mendes, B.F. (1975). A bacteriological survey of Washrooms and Toilets. Retrieved from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2129632/pdf/jhyg00065-0022.pdf>

22. MIT (2011). Life Cycle Analysis of Hand Drying Systems. Massachusetts Institute of Technology. Commissioned by Dyson Inc. Retrieved from :  
<http://msl.mit.edu/publications/HandDryingLCA-Report.pdf>
23. Montville, Rebecca. (2002). *Risk assessment of hand-washing efficacy using literature and experimental data*. 3rd International Conference of Predictive Modelling in Foods. Vol. 73. Issue 2-3. Pp. 305-313. Retrieved from:  
<http://www.sciencedirect.com/science/article/pii/S0168160501006663>
24. Person, B. Et al. (2013). *A Qualitative Evaluation of Hand Drying Practices among Kenyans*. PLOS One Open Access Journal. Vol. 8. Iss. 9. Pp.1-6. Retrieved from:  
<http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0074370>
25. Redway, K. (2015). *Comparison of virus dispersal and aerosolization by different hand-drying devices*. The European Journal of Public Health. Vol. 25. Iss. 3. Pp. 152-164. Retrieved from: [http://eurpub.oxfordjournals.org/content/25/suppl\\_3/ckv171.059.extract](http://eurpub.oxfordjournals.org/content/25/suppl_3/ckv171.059.extract)
26. Srinivasan K. Arun. (2009). *Ecolabeled paper towels: Consumer valuation and expenditure analysis*. Journal of Environmental Management. Volume 90. Issue 9. Pp. 314-320. Retrieved From:  
<http://www.sciencedirect.com/science/article/pii/S0301479707003507>
27. Wang, Qi. (2013). *Bacteria Fighting Paper Towels: The Influence of Selenium Nanoparticles*. Bioengineering Conference (NEBEC). Retrieved from:  
<http://ieeexplore.ieee.org/document/6574342/>
28. Wang, Qi. (2014). *Inhibition of various bacterial growths on paper towels through the use of selenium nanoparticles*. 40th Annual Northeast Bioengineering Conference (NEBEC). Retrieved from: <http://ieeexplore.ieee.org/document/6972971/>
29. Yamamoto, Yukiko. (2005). *Efficiency of Hand Drying for Removing Bacteria from Washed Hands: Comparison of Paper Towel Drying with Warm Air Drying*. Journal of Infection Control and Hospital Epidemiology. Vol. 26. No. 3 pp. 316-320. Retrieved from: [http://www.jstor.org/stable/10.1086/502546?seq=1#page\\_scan\\_tab\\_contents](http://www.jstor.org/stable/10.1086/502546?seq=1#page_scan_tab_contents)