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UNDERSTANDING THE SUSTAINABILITY OF ECO-LABELED PRODUCTS WHEN COMPARED TO CONVENTIONAL ALTERNATIVES

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ABSTRACT

Sustainability considerations are becoming an intrinsic part of product design and manufacturing. Today's consumers rely on package labeling to relay useful information about the environmental impact of a given product. As such, eco-labeling has become an important influence on how consumers interpret the sustainability of products. Three categories of eco-labels are theorized: Type I focuses on the use of labels that are certified by a reputable third party. Type II are eco-labels that are self-declared, potentially lacking scientific merit. Type III eco-labeling indicates the public availability of product LCA data. However, regardless of the type of eco-label used, it is uncertain if eco-labeling directly reflects improved product sustainability. This research focuses on exploring if eco-labeling reflects improved product sustainability by comparing eco-labeled products to conventional alternatives. To do this, we perform a comparative study of eco-labelled and comparable conventional products using a triple bottom line sustainability analysis, including environmental, economic, and social impacts. Here we show that for a selected set of products, eco-labeling does, in fact, have a positive correlation with improved sustainability. However, Type II eco-labeling shows a slight negative correlation with product sustainability. We found only one eco-labeled product (with Type II labeling) that had reduced environmental impact over the conventional alternative. Additionally, the majority of the eco-labeled products in the study are cheaper for the consumer in both initial cost and costs incurred throughout the product's lifetime. In general, the results confirm that most eco-labels are indicative of improved sustainability. Future research can work towards improving Type II eco-labels, and promote policies that protect against false sustainability claims.

INTRODUCTION

Manufacturing industries are currently experiencing a paradigm shift in that they are not only focusing on profit, but also considering the effects of sustainability in manufacturing [1]. According to the United States Department of Commerce, "Sustainable manufacturing is defined as the creation of manufactured products that use processes that are non-polluting, conserve energy and natural resources, and are economically sound and safe for employees, communities, and consumers" [2]. Sustainability, in the context of this work, has a *triple bottom line* featuring environmental, economic and social considerations.

Along with the manufacturing shift towards sustainability, consumers are caring more about product sustainability. The

2013 Green Gap Trend Tracker by Cone Communications found in 2013 that 71% of American consumers consider the environment when purchasing goods [3]. In addition, according a study of 10,000 online consumers conducted by the Natural Marketing Institute (NMI), 40% of consumers chose sustainable product alternatives compared to conventional products. Of this 40%, 50% of these consumers were millennials (ages 21-25). Millennials are also most likely to spend more on sustainable alternatives, and to check labeling for environmental information. The study concludes that millennials are three times more likely to check for sustainable labels and spend more on sustainable products than Generation X (ages 35-49), and twelve times more so than Baby Boomers (ages 50-64) [4]. This preliminary research shows that sustainability-labeled products show a growing economic and social impact especially when considering younger consumers and future generations.

Eco-Labeling

Sustainable thinking coupled with self-branding initiatives has led to more consumer goods manufacturers to employ eco-labeling on product packaging. Eco-labeling is "an environmental label or declaration that provides information about a product or service in terms of its overall environmental character, a specific environmental aspect or number of environmental aspects" [5]. Marketing products as "sustainable" is intended to affect end customers, as it lends a sense of responsibility to the user. As more consumer behaviors trend toward concern for the environment, eco-labeling is designed to corroborate and influence that concern.

The International Organization for Standardization (ISO) has classified eco-labels into three types: Type I, Type II, and Type III [6]. Type I labels are third-party-certified labels that indicated a product adheres to specific environmental guidelines [6]. The Rainforest Alliance certified seal, shown in Figure 1, is an example of Type I label [7]. Type II eco-labels address a single attribute of environmental information, and are self-declared [6]. Green labeling such as the flower in Figure 2 or other imagery that invoke a sense of environmental friendliness are examples of Type II labels. Type II labels are not substantiated by third-party entities, and can be added to any product. Type III labels are third-party-certified labels based on Life-Cycle Assessment (LCA) information [6]; as shown in the hand dryer comparison of Figure 3.

FIGURE 1 RAINFOREST ALLIANCE CERTIFICATION SEAL [7]

FIGURE 2 GREENWORKS ALL-PURPOSE CLEANER MANUFACTURED BY CLOROX [8]

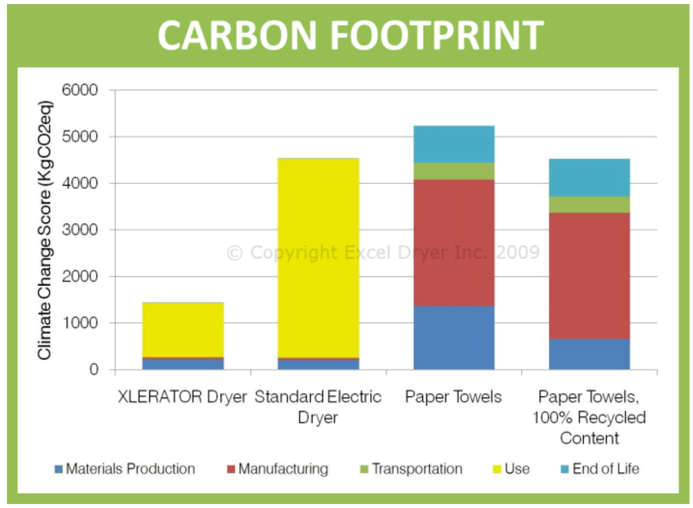

FIGURE 3 EXCEL HAND DRYER LCA COMPARISON [9]

However, the validity of an eco-label varies with its certification authority. First-party certifications are autonomous, and products with first-party certifications are not tested or validated by an independent agency. These eco-labels are referred to as "self-declaration." Second-party certifications are initiated by industry associations for their members' products. Third-party certifications are given by either public or private entities that un-associated with the product manufacturer [10].

Potential Concerns with Eco-Labeling

Eco-labeling on product packaging is designed to inform consumers of the environmental impact or relative sustainability of the product. One concern with eco-labels is that they may not represent the overall improved sustainability of a product. For example, Type II labels that indicate the use of recycled packaging may reflect sustainability improvement of the packaging but not the product within.

Eco-labels also act as a potentially dubious marketing strategy to consumers. Predatory marketing strategies are possible because of the complexity in understanding how eco-labels are classified. A recent example of this is Volkswagen, which marketed cars that were defined to be within the emission levels set by US Environment Protection Agency, but tests were found to be fabricated, and the vehicles in question were creating emissions outside the range of acceptable values [11].

The goal of this research is to identify the validity of eco-labeling with respect to product sustainability by performing a comparative study of eco-labeled products to equivalent un-labeled products with identical functionality. There have been similar studies performed by comparing the environmental sustainability of innovative products to common products [12], the outcome of which indicated that new-to-market, innovative products did not have improved sustainability over conventional products.

The focus of this study is to compare eco-labeled products against conventional alternatives. This comparison will be used to understand if eco-labeling is an indicator of improved product sustainability. Product sustainability will be evaluated using triple bottom line analyses: ReCiPe via GaBi for environmental impact, modified Stanford building LCCA for economic impact, and a developed in-house S-LCA for social impacts. The comparisons are conducted from product inception to end of life.

LIFE CYCLE ASSESSMENT

Life Cycle Assessment is a means of assessing the environmental impacts of a product from its cradle to grave (from raw material processing into materials, manufacturing, assembly, distribution, use, and end of life) [13]. Today, LCA has been extended to asses all the three pillars of sustainability.

Economic LCA methods estimate the material and energy resources required and environmental impact resulting from activities in our economy [14]. Some of the tools used for conducting Economic LCA are EIO LCA (Economic Input-Output LCA) and LCCA (Life Cycle Cost Analysis) [15,16]. For the purposes of this research LCCA has been chosen for the economic LCA; since it measures dollar cost, and thus more applicable to the consumer. LCCA is a method that assesses the total cost of a product; this included national product cost, and consumable cost over time. In this study, a consumable is considered to be any resource that is required to operate the product during its lifetime.

Social LCA (S-LCA) measures both the positive and negative sociological impacts of a product through its life cycle. S-LCA makes use of generic and geographic specific data, and varies from quantitative to qualitative datasets and complements the environmental LCA and LCCA [17]. S-LCA is an emerging LCA area of interest. It allows researchers to qualify how people themselves are effected by a product or process. This includes, but is not limited to, how a product effects a user emotionally, mentally, and physically; along with understanding the social implications on human health and happiness of manufacturing in a given location.

LCA is primarily used for determining the various quantifiable impacts relating to the triple bottom line of a given product or process. LCA studies have become widespread, and are employed in applications ranging from research linking product design decisions and environmental impact, to industries using LCA in building certification [18,19].

It is important to note that LCAs are often informed by life cycle inventories. Life cycle inventories provided a comprehensive database about the process or product on which the LCA will be performed. This LCI data is often personalized to only to include data required to complete a given LCA method. Bill of materials, manufacturing locations, and end-of-life disposal methods are often found in LCIs of products.

PURPOSE

The purpose of this research is to characterize the relationship between the three pillars of product sustainability and product eco-labeling. This can be achieved by comparing eco-labeled consumer products with un-labeled counterparts with respect to environmental, economic and social impacts. This research solely focuses on comparison through LCA methods; by doing so, we can provide a quantitative analysis of product sustainability. It is our intent that this research contributes to the growing interest in understanding the life cycle impact of consumer goods, and to encourage substantiated sustainability claims in influencing consumer purchasing decisions.

PROJECT SCOPE & BOUNDARY DEFINITION

The goal of this study is to understand the correlation between eco-labeling and product sustainability. In addition, this work aims to discover if eco-labeling is indicative of improved product sustainability. To discover these trends, we are using environmental LCA, LCCA, and S-LCA to measure the triple-bottom-line impact of eco-labeled products. These eco-labeled products are then compared to conventionally labeled alternatives to benchmark the sustainability performance of the eco-labeled products.

The study consists of nine consumer products within four product categories: water bottles, trash bags, hand dryers, and chainsaws. These products are chosen because they represent a wide breadth of products that consumers may commonly use. Water bottles and trash bags are chosen to represent consumables that are widely ubiquitous. Chainsaws and hand dryers are chosen to represent more industrial products that see both home and commercial use. Furthermore, these products have higher consumable use over their life spans compared to the other two categories.

The triple-bottom-line impact of these products are measured using ReCiPe via GaBi, a modified Stanford building LCCA, and an in-house S-LCA [16,20].The LCCA and S-LCA methods are chosen because they align more closely with the consumer bottom line.. ReCiPe is chosen as the environmental LCA because it offers extensive measurements of environmental impact over many impact indicators, ensuring that our analysis does not oversimplify the areas of impact.

METHODOLOGY

The methods employed in this research are applied to a nine-product case study. The case study is designed to look at the triple bottom line of product sustainability by comparing conventional, non-eco labeled products to their eco-labeled counterparts. To measure the overarching sustainability of each product in the case study set, we employ ReCiPe via GaBi for environmental impact analysis, a modified Stanford LCCA for economic impact analysis, and an in-house S-LCA for social impact analysis.

Product Selection

The four product categories and the nine products explored in the study are selected to represent a variety of common consumer products, that is, we expect that most first-world users have used or purchased some version of the chosen products. Table 1 displays the nine products and four product categories selected for use in this study.

The first category is the "water bottle" category. This product group features three products: a metal reusable bottle, a disposable plastic bottle, and a plastic reusable bottle. These bottles all represent the 16.9 oz. format for a drinking water container. The metal reusable bottle features insulated stainless steel construction with removable HDPE lid [21]. The single-use bottle is a standard disposable water bottle commonly found in stores around the world. The selected model is a reduced-plastic single-use water bottle that has become increasingly common [22]. The plastic reusable bottle is made of polycarbonate with a polyethylene lid and strap [23]. The metal reusable bottles and plastic reusable bottles are considered to be the more environmentally-friendly alternatives to the single use bottle. Both of these products use of Type II eco-labels, stating that by using their product consumers are reducing plastic waste, which in-turn promotes less environmental impact and increased sustainability [24,25]. Since these products both directly state that they are reducing the use of single-use bottles, such bottles are selected to represent the conventional product.

TABLE 1. LIST OF CONVENTIONAL AND ECO-LABELED PRODUCTS SELECTED FOR COMPARISON

#	Product	Category
1	Metal Reusable Bottle	Water Bottle
2	Single Use Bottle	
3	Plastic Reusable Bottle	
4	Conventional Trash Bag	Trash Bag
5	Eco Trash Bag	
6	Hand Dryer	Hand Dryer
7	Eco Hand Dryer	
8	Gas Chainsaw	Chainsaw
9	Eco Electric Chainsaw	

The second product category consists of the two trash bag products. The conventional trash bag is made from polyethylene film. The eco alternative is made from 55% recycled plastic with 16% post-consumer recycled plastic content. The eco trash bag packaging includes a Type II eco-label, stating the bags are a more sustainable choice than 100% virgin plastic bags [26].

The third product category includes electric hand dryers. This family is unique in that both products are made from the same manufacturer. The two products chosen for the study are a standard hand dryer model and the eco hand dryer. Both of these products have sustainability claims and have eco-labels Types I and II. Both products feature Type I eco-labels by LEED, GreenSpec, Greener Product, and Green Business Bureau [10]; as well as Type II labeling stating that these products will save money compared to paper towels. In addition, the standard hand dryer models were the subject of a company LCA, enabling it also have Type III labels [27].

The final product category is the chainsaw group. The conventional chainsaw is gas-powered, and the eco-alternative is an electric chainsaw. Greenworks Power Tools makes Type II claims stating their products are zero emission, do not pollute, or require maintenance. They also claim to have a Type I Energy Star label, but do not display the Energy Star seal [28].

Product Life Cycle Inventory (LCI) Analysis

After identifying the products that will be used in the study, the LCI for each of the products is found. This information includes: product name, make, model, description, manufacturing location, consumer price, consumables price, use phase characterization, and bill of materials. The bills of materials include: component name, quantity, material, manufacturing process, and component weights.

All LCI information (excluding the bills of material) was sourced using manufacturer websites; much of this information is listed in the cited product sources. The bills of materials were informed by the CMU Design Decisions Wiki, and were determined empirically for simpler products such as the water bottles and trash bags [29]. Bill of materials information such as component weight was found via SolidWorks, requiring user-created CAD models or source models from GrabCAD [30,31]. Material and manufacturing processes were identified by referencing Manufacturing Processes for Design Professionals [32]. The use phase of the products was defined by a functional unit featuring one year of normal use per product [33]. Normal use is defined by the statistically informed average consumable use of each product. The functional unit was kept consistent for each product within a product category. The functional unit of each product category was informed using relatable use statistics or recommendations of intended product use by the manufacturer. For example, the water bottle product category has a functional unit based on consuming 8-8 oz. glasses of water a day. Use information that could not be derived by the method listed above were found via consumer usage information from internet sources, such as forums and product reviews.

Overview of LCA Methods

Through this study, we focus on the triple bottom line of sustainability by employing LCA, LCCA, and S-LCA. LCA focuses on quantifying the environmental impacts of the product. LCCA explores the economic impacts of the products. Lastly, S-LCA focuses on the social implications and impacts of the products of the study. In the next sections, we will detail the selection of the specific methods employed and how they are used.

Environmental LCA – ReCiPe via GaBi

The LCA method chosen for this study is ReCiPe implemented in the software GaBi. ReCiPe is a robust LCA tool that features 21 unique output indicators [34]. Of these 21 indicators, 18 are mid-point indicators while three are normalized from the mid-points as end-point indicators. Mid-point indicators are information such as global warming potential, environmental toxicity, and CFC-11 emission. The three normalized end-point indicators are human health (DALY), ecosystem quality (species depletion) and resource cost. DALY is the measure of damage to human health by the addition of the indicators *years of life lost* and *years of life disabled*. The loss of species per year is a normalized measurement of the damage to the ecosystem, and represents the fraction of species lost over a given area during a set time. Lastly, resource usage is the measure of damage to resource availability quantified by dollar cost per kg. These normalized end-point indicators offer an easy-to-understand alternative to the mid-point indicators in the form of human health, species loss, and resource loss.

The GaBi program aids in the implementation of many LCA methods with the use of extensive databases regarding material selection, manufacturing processes, and disposal [20]. GaBi features a graphical interface that allows users to select this information as it pertains to their project. This interface then allows the user to create life cycle flows from cradle to grave. Once cradle-to-grave input is completed, GaBi displays the indicators relevant to the chosen LCA method. For this project, the ReCiPe LCA method was implemented with GaBi, using the LCI product information. GaBi also allows for the manual creation of processes to be added to a product life cycle. This functionality was used in order to include the use phase of the products with in their individual LCA.

Economic LCA - Stanford Building LCCA

The economic LCA chosen for this study is a modified version of Stanford's Building LCCA. This LCCA method is employed to quantify the life cycle cost of an entire building [16]. This method looks at the lifetime cost indicators of building utilities, maintenance, service, system replacements, and initial project cost indicators. A theorized building is separated into seven categories: energy systems, mechanical systems, electrical systems, building envelope, siting, and structural systems. The user of this method then selects potential options for each building category. Each alternative is compared using a cost-benefit analysis that is extrapolated to the indicators listed above to provide the life time cost of the specific option. Since the study presented in this paper focuses on consumer products and not buildings, the Stanford LCCA method was adapted and simplified to quantify the consumer cost of products. The cost indicators used for this study are consumable cost and initial cost to the consumer. The LCCA method was adapted to look at alternatives for consumable cost and initial consumer cost via product comparison instead of systems comparison. Using the modified Stanford LCCA framework allows for understanding the economic impact associated products within each product category. The LCCA was implemented using the information from the product LCI. Product costs were found on manufacturer websites or websites that sell the product. Consumable costs were calculated using average cost of the consumable across the US; e.g. water, as a consumable, was calculated to cost the national average USD per gallon.

Social LCA – In-house S-LCA

An in-house method was created to explore the social impact of the products in the study. This S-LCA method includes 4 impact categories based on relevant literature that addresses social impacts. These categories are: the location of manufacturing as it relates to labor laws [35], social outlook/perception [36,37], user safety [38], and ease of maintenance [39].

- The *location of manufacturing* category looks at where the product is made and surrounding labor laws and practices that could have impacted the product's social sustainability. This information was gathered based on the LCI manufacturing locations that were found during the sourcing of product information.
- *Social outlook* is informed by external surveys on how the product is perceived and thereby answering the question: Is the product viewed positively or negatively?
- The *user safety* category includes source reports of injuries that have occurred when using a specific product. This category also lists any warning about potential product dangers that are stated by the manufacturer.
- The *ease of maintenance* category explores the variation in maintenance required for different product alternatives.

Assumption and Limitations

As with many previous works that employ LCI data, there are several assumptions made for the data acquired for this study. The use phase is assumed to be consistent over time, and informed by statistical data based on use of the product. For example, eight eight-ounce glasses of water a day is consistent for every day of the year and does not fluctuate.

Due to the limitations of the data available with in GaBi, all manufacturing is modeled as having taken place in the US regardless of the LCI information on manufacturing location; note that this only affects the environmental LCA portion of the study. However, GaBi only has manufacturing data for processes that take place in Europe. It is assumed that the input/output for each manufacturing process itself are the same anywhere in the world. In order to make the assumption that manufacturing takes place in the US, manufacturing inputs such as lubricating oils, water, and electricity are sourced from the US database within GaBi. To coincide with this assumption, all product use phases are assumed to have occurred in the US; consumable resources are also from the US database. Products that have components that share manufacturing and material types have identical manufacturing flows, making the only variable component weight. This assumption insures that similar components across all products don't have variation in impact due to differing consumable sources (West Us versus East Us), and differing disposal methods.

Transportation is omitted from the LCI to avoid introducing significant uncertainty to the study, as transportation data for consumer products are generally not made publically available; it is instead assumed that all products see the same transportation distances and methods.

The disposal method for all products is assumed to be incineration. It is recognized that disposal methods have a large impact on LCA data. However, assuming separate disposal methods for each product could further skew the data; there is large variation in the disposal methods used from person to person.

The perceived lifespans of the products used to generate the results of the LCCA were determined empirically. Product lifetime, for the most part, is inconsequential since most products within a given product category have the same perceived lifespan; the water bottle family is the only exception. Water bottle lifespans were chosen empirically based on personal use. Furthermore, manufacturing location is known to have an effect on initial product costs because of this initial cost is only a product of purchasing price (in the US).

DATA

The ReCiPe indicator data is available in Table 2. This data is the raw indicator data collected through the GaBi software that highlights each product's individual impact per indicator category. Table 3 shows the individual product results of the five impact categories of the S-LCA study. Due to sizing constraints, Tables 2 and 3 appear in the Appendix.

RESULTS AND DISCUSSION

Environmental LCA Results

The results for the environmental impact analysis were developed by calculating the average percent change (either positive or negative) between the analysis of the eco-labeled products and their conventional alternatives. First the percentage of change was calculated per indicator; then the overall average percentage of change (between all indicators) was calculated.

This percentage is global in nature, since it is the average overall change between all the indicators. Table 4 shows the percent net change in impact when an eco-alternative is compared to the conventional product in the same product category.

TABLE 4. AVERAGE PERCENT CHANGE OF IMPACT INDICATORS

#	Product	Impact Change (%)
1	Metal Reusable Bottle	-53.99
2	Single Use Bottle	control
3	Plastic Reusable Bottle	-99.29
4	Conventional Trash Bag	control
5	Eco Trash Bag	-19.34
6	Hand Dryer	control
7	Eco Hand Dryer	-115.63
8	Gas Chainsaw	control
9	Eco Electric Chainsaw	+0.605

From these quantitative results, it is clear that the plastic reusable bottle is the best alternative to a single use water bottle. However, the results show that there is a greater need for eco-labeling used for the reusable bottles to be accurate and truthful. The eco trash bags and the eco hand dryer both have a positive correlation between eco-labeling and improved sustainability when only considering environmental impact. Lastly, the eco electric chainsaw was the only product that had a negative correlation between having an eco-label and environmental impact as compared to a conventional product. The fact that the electric chainsaw manufacturer does not have the Energy Star seal on their environmental page made its claims less trustworthy, and these results reinforce that sentiment. The claims may be true that the electric chainsaw does not itself emit pollution, but the electricity used during the use phase of the product does have embedded emissions due to electricity generation. Thus, the current Type II eco-label of the eco chainsaw may be misleading.

Economic LCCA Results

The LCCA data was calculated by extrapolating the use-phase information for product consumables and relating those use scenarios to the cost of the consumables. This information was then added to initial cost of the products. The initial cost of each product is divided by the assumed lifetime of product. This data was source via statistical averages. Table 5 shows the cost results for the studied products.

TABLE 5. PRODUCT COST DURING ONE YEAR OF USE

#	Product	Initial Cost (USD per unit)	Life-span (Yr)	Consumable Cost (USD)	Total Cost per Year (USD)
1	Metal Reusable Bottle	30.95	5	1.14	7.33
2	Single Use Bottle	0.8	SU[1]	-	110.6
3	Plastic Reusable Bottle	9.00	3	1.14	4.14
4	Conventional Trash Bag	0.21/bag	SU[1]	-	21.84
5	Eco Trash Bag	0.34/bag	SU[1]	-	35.36
6	Hand Dryer	480	12	67.3	107.3
7	Eco Hand Dryer	450	12	24.82	62.32
8	Gas Chainsaw	329	10	1.56	34.46
9	Eco Chainsaw	249	10	0.58	25.48

1. SU means Single Use

In general, every eco-labeled product studied (except the eco-trash bag) indicated an increased value and cost savings when compared to the conventional alternative. The largest differences in costs (based on percentage) were evident in the reusable bottles when compared to the single use water bottles.

Furthermore, the plastic reusable bottle has a lower economic impact (to the consumer) than the metal bottle. However—though this consideration is outside of the scope of this study—the metal bottle should last longer than the plastic bottle under normal use conditions. From these results, it can be concluded that for most products in the study, eco-labeling is indeed accurate when used to market an eco–product as a money-saving alternative.

Social LCA Results

The in-house Social LCA rendered both quantitative results and more qualitative results based on the four impact categories identified. The results of the social LCA are shown in Table 3 in the Appendix. From these results, some of the key points are that reusable plastic bottles are better than both metal reusable bottles and single-use bottles if the country of production has better labor laws and the number of incidents reported is less; also carcinogenic content is not found in these bottles. The only study in which single-use water bottles have improved SLCA indicators are when they are used during events of natural distress or calamity, due to the fact that they are easy to transport and are perceived as safe. While comparing conventional trash bag to eco-friendly trash bags, the eco-friendly trash bags are considered to be more socially sustainable. Similarly, eco hand dryers and the eco electric chainsaw gain an advantage over their conventional counterparts. One primary concern with the eco electric chainsaw is the possibility of the electronic circuit malfunction, which might cause severe injuries, but there are no reports of such incidents.

Sustainability Discussion

Overall, the eco-label products are indicative of a more sustainable products over conventional alternatives within their families. The water bottle family saw vast improvements in all three areas. It is interesting to note that the plastic reusable bottle is the most sustainable option of the three products. As such, it had less instances of human health hazards, less environmental impact, and was roughly half the cost of the metal reusable water bottle. The trash bag family was the least improved, sustainability-wise, over the conventional product. There is only a slight improvement in the social aspects of the trash bag comparison, and a negative impact on cost. The eco hand dryer is a notable improvement over the conventional alternative, in all areas of sustainability. The eco hand dryer costs less than the conventional hand dryer, had a reduced environmental impact, and had improved social characteristics - namely improvement in maintenance and user safety. The chainsaws perform similarly socially; while the eco alternative excels in cost but fails in environmental impact. Socially, it can be argued that the lack of interaction with hazardous fuels increases the user safety of the eco chainsaw; thus giving the social advantage to the eco chainsaw.

CONCLUSION

The purpose of this study was to use three LCA methods: ReCiPe via GaBi, Modified Stanford LCCA, and S-LCA, to discover if eco-labeling correlates to improved product sustainability. This was done by comparing the LCA indicator results between eco-labeled products and their conventionally labeled alternatives. The results show that most eco-labels of Types II and III are credible. However, due to having one product claim in the study that is misleading indicates that there are false sustainability claims labeled on products. These results also conclude that eco-labeled products tie their eco-labels to monetary savings as an incentive to invest. However, a larger case study is required to substantiate this claim for all eco-labeled products. This work can serve as the starting point to encourage the widespread use of trustworthy eco-labeling by creating a foundation in LCA methods to assess product sustainability claims.

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APPENDIX

TABLE 2. ReCiPe INDICATOR OUTPUT DATA PER PRODUCT

–		MID-POINT INDICATOR													END-POINT INDICATOR	
#	Product	CO2(kg)	SO2(kg)	P(kg)	CFC-11(kg)	Oil (kg)	1,4-DB(kg)	U235(kg)	N(kg)	Fe(kg)	PM10(kg)	NMVOC(kg)	Water(m2)	Species.yr	DALY	$
1	Metal Reusable Bottle	1.09	3.58E-03	3.58E-03	3.98E-11	0.332	0.608472	0.0147	9.50E-04	1.06	1.62E-03	3.18E-03	0.254	8.69E-09	2.37E-06	5.41
2	Single Use Bottle	72.8	0.135	1.59E-03	1.03E-08	41.8	34.117	3.41	0.0322	0.239	0.0417	0.152	26.1	5.92E-07	1.37E-04	6.71E+02
3	Plastic Reusable Bottle	0.517	9.97E-04	9.93E-06	6.83E-11	0.268	6.02E-02	2.99E-02	2.73E-04	1.47E-03	3.14E-04	9.39E-04	3.63E-01	4.19E-09	8.47E-07	4.3
4	Conventional Trash Bag	1.83E-02	3.38E-05	6.51E-07	1.50E-12	1.53E-02	0.004123	8.54E-04	8.55E-06	6.07E-05	1.09E-05	3.10E-05	1.30E-02	1.52E-10	3.13E-08	0.246
5	Eco Trash Bag	0.0137	2.67E-05	7.06E-07	1.88E-12	8.66E-03	0.004157	7.42E-04	6.15E-06	4.99E-05	8.71E-06	2.20E-05	8.21E-03	1.15E-10	2.43E-08	1.39E-01
6	Hand Dryer	412	1.2	4.17E-04	1.58E-07	121	1.53E+01	4.49E+01	0.191	36.3	0.327	0.583	164	3.27E-06	6.73E-04	1.95E+03
7	Eco Hand Dryer	166	0.494	3.38E-04	6.01E-08	5.01E+01	1.07E+01	1.75E+01	0.0837	3.57E+01	0.144	0.254	81.9	1.33E-06	2.78E-04	806
8	Gas Chainsaw	13	0.039	2.32E-04	1.94E-09	7.27	1.94852	0.637	0.0106	1.56	0.0282	0.0297	4.95	1.04E-07	2.69E-05	117
9	Eco Electric Chainsaw	16.4	0.0372	2.29E-05	4.74E-09	5.24	1.46E+00	0.989	7.98E-03	1.55	0.0165	0.025	5.53	1.30E-07	2.83E-05	84.3

TABLE 3. S-LCA RESULT

#	Product	Country of Production	Social Perception	User Safety	Ease of Maintenance
1	Metal Reusable Bottle	China (Labor laws & Practices are low compared to USA)	Good (+ve)	Choking Hazards (6 incidents of spouts breakage reported in one year)	Easy to Maintain
2	Single Use Bottle	USA (Labor laws are pretty strict)	Poor (-ve)	Choking Hazard/ Warnings about cancer	Not Required
3	Plastic Reusable Bottle	USA (Labor laws are pretty strict)	Good (+ve)	Choking Hazards (1 incident reported in 2013)	Easy to Maintain
4	Conventional Trash Bag	USA (Labor laws are pretty strict)	Poor (-ve)	Danger of Suffocation	Not required
5	Eco Trash Bag	USA (Labor laws are pretty strict)	Good (+ve)	Danger of suffocation	Not required
6	Hand Dryer	USA (Labor laws are pretty strict)	Unknown	Chances of burns	Regular Maintenance required
7	Eco Hand Dryer	USA (Labor laws are pretty strict)	Unknown	No chance of burns	Less Maintenance as heating components are not involved
8	Gas Chainsaw	USA (Labor laws are pretty strict)	Unknown	Exhaust fumes are highly harmful. Interaction with flammable materials	High Maintenance. Possibly need to mix fuels every fill up.
9	Eco Electric Chainsaw	USA (Labor laws are pretty strict)	Unknown	Circuit Malfunction and Battery Explosion	Less Maintenance