Sustainability Stoplight

An Interactive Qualifying Project Report

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Abstract

This project is inspired by The Poverty Spotlight created by El Fundación Paraguaya, which allows its users to evaluate themselves in terms of their socio-economic status, and provide them with tools and tips to improve it. We have adapted that idea into an Android application which will allow users to evaluate their sustainability and learn how to be more sustainable. This was accomplished through a survey administered through the app, and built-in recommendations that are dynamically generated based on the user's response. The Poverty Spotlight was designed with the impoverished citizens of Paraguay in mind; our project however, will initially focus on students in the Worcester area with the potential to expand to larger audiences. We administered a sample survey to WPI students and other locals in order to ensure the quality and relevance of the questions asked. We have consulted industry professionals such as Dr. Martin Burt and Professor Tien Guo to ensure the design of the application was acceptable. The app was successfully created, and all the desired functionality is present.

Acknowledgements

We would like to thank all the individuals that responded to the Qualtrics survey. Using their responses, we were able to improve the quality and usefulness of the questions.

We acknowledge with gratitude our advisor, Professor John Orr, for his continuous support and supervision in every step of the project. We would also like to thank Professor Tien Guo, who helped guide the development of the application.

Finally, we would like to thank Dr. Martin Burt, whose Poverty Stoplight inspired this project.

1 Introduction / Goals

The United States and the world have recently been experiencing the phenomenon of global warming. Additionally, global sea levels are rising and extreme weather events are becoming increasingly common [1]. Tropical rainforests will be wiped out by the middle of the 21st century if deforestation rates remain unchanged [2]. These are only some of the problems our Earth faces. Climate change, the acidification of the oceans, rising sea levels, and a shortage of fresh water are just a few of the possible consequences of humanity's actions. Thus, living sustainably becomes essential to ensure future generations will be able to experience the incredible world we have today.

The goal of this project is to develop a way to educate and mobilize individuals toward a more sustainable future. The tool used to achieve this goal is a mobile application that features a survey consisting of sustainability-centered questions that anybody could complete, and would then advise them on how to improve their level of sustainability depending on their responses. This approach was inspired by the Poverty Stoplight, in that it motivates the individual to improve themselves, and as a result, their society. This application would be an effective way to increase education and make a positive impact due to its accessibility and simplicity. The metrics used determine the sustainability of an individual will be synthesized from a combination of statistics regarding the average American's resource usage, along with other research which will help account for the many differences that exist on an individual level. These metrics will be implemented in an application that will allow users to evaluate themselves, and will then educate the user how to best improve their personal situation. The survey has been administered to test subjects through a Qualtrics survey in order to ensure the questions within are straightforward, non-leading, and easily answered.

The final product of this project is the application designed for Android devices. It consists of a survey section of carefully selected questions designed to target various aspects of sustainability and in such a way that the user is inclined to answer honestly. Once a user completes this section, there will be a recommendations section that provides the user a grade based on their performance using an algorithm that will be described in the methodology. Additionally, it will provide the user recommendations on how to improve their performance in the future. The following section will provide a thorough definition of sustainability, what living sustainably is on an individual level, as well as a means to measure individual sustainability in any given area.

2 Background:

2.1 Introduction / Poverty Stoplight

The Poverty Stoplight is a system developed by the Fundacion Paraguaya in order to eliminate the various aspects of poverty that afflict locals in Paraguay, though can be utilized by any other individuals with slight adjustments for the locale. It allows individuals to track their current poverty status and plan a way to deal with it.

Through the Poverty Spotlight's visual survey, "families self-assess their level of poverty in 50 indicators grouped into 6 dimensions of poverty which are: Income & Employment, Health & Environment, Housing & Infrastructure, Education & Culture, Organization & Participation and Interiority & Motivational" [3]. The concept of the indicators is an important aspect of the spotlight. The concept of dividing the spotlight into many sub-categories is also quite practical.

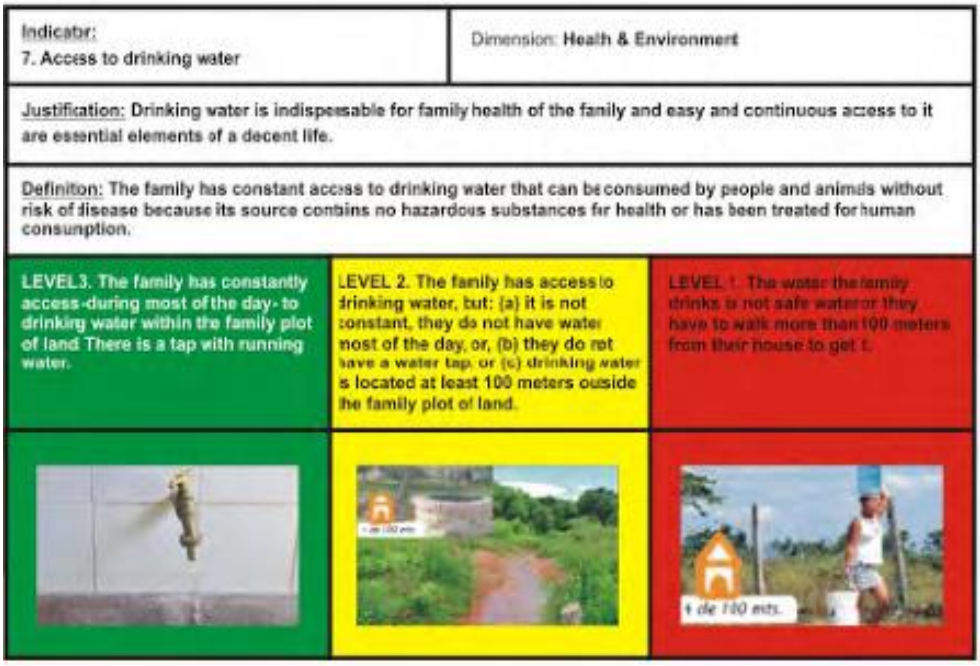

Figure 1: Visual representation of a Poverty Stoplight indicator. [3]

The application allows for users to directly influence their own levels of sustainability. By giving users the information they need to live a more sustainable life, they will be able to begin to make changes in their lifestyles. They can begin with simpler improvements, such as buying reusable grocery bags or using LED lights. Although these improvements seem insignificant individually, the cumulative impact can be quite relevant.

Despite the sustainability issues in an urban environment, there are not inherently fewer issues if one were to live in a rural or suburban area. While it may seem that rural or suburban

houses consume less than urban ones, there is evidence that suggests otherwise. For example, suburban or rural homeowners often own large portions of land outside of their house that needs to be maintained with large amounts of water, fertilizer and other materials. Similarly, the heating of an apartment building is much more efficient per capita than heating one family living in a single house [4]. Additionally, urban individuals make much better use of infrastructure such as roads and utilities. Their suburban and rural counterparts do not, due to their distance from others. In other words, the return on investment for a state improving a road in the city is much greater than a road in the countryside due to the former experiencing far more traffic that the latter.

Sustainability is an extremely broad topic, and in order to properly evaluate it, all relevant dimensions of sustainability must be included in the equation. The importance of these categories are explained in the background in order to give an understanding of why certain resources need to be used sustainably. Next, we break down what factors into the usage of these resources on a per household basis. Using these metrics, we can further enhance our definition of what is and is not sustainable.

2.2 Water

One of the primary facets of sustainability is clean water. The vast majority of it is obtained from underground as well as bodies of fresh water, with minimal contributions from other sources such as desalination [5]. In Massachusetts, the average amount of water used per person per day is 57 gallons [6]. Many people in the United States rely on aquifers, underground soil or rock units that contain fresh water that is pumped to the surface, for their water. They represent roughly 30 percent of the freshwater in the world, with around 68 percent trapped in glaciers or ice caps and less than one percent found above ground in lakes, rivers or swamps [7]. Although water is a renewable resource and these aquifers replenish naturally, humans are drawing water from aquifers at a far greater rate than they can refill on their own. Additionally, if water is withdrawn past certain levels, it will never be able to fill all the way back beyond these levels [8]. However, consumption is not the only thing that is threatening aquifers. Rising sea levels are contaminating aquifers near the coast with salt and rendering them unusable [9].

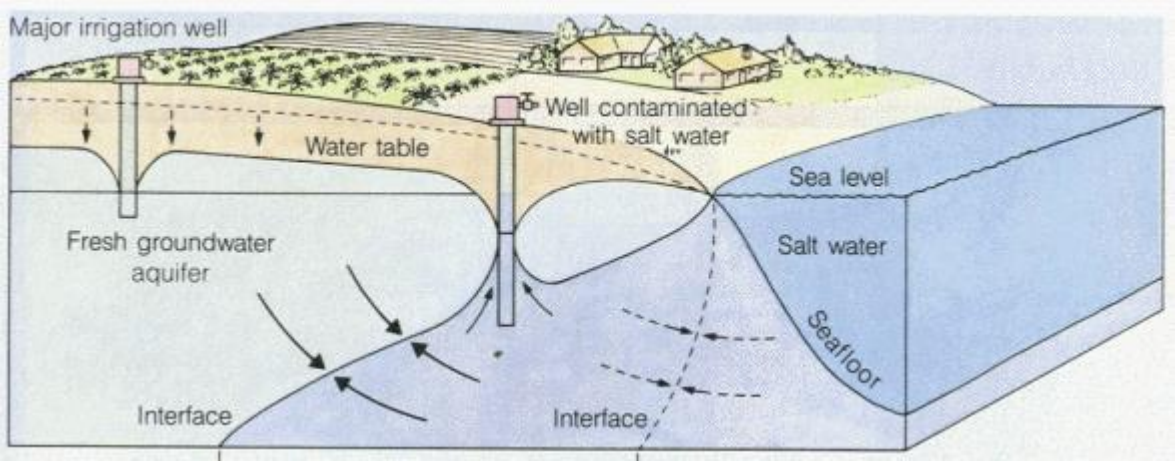

Figure 2: Depiction of saltwater intrusion into freshwater aquifers [10]

Despite above ground freshwater accounting for less than 1 percent of total freshwater, it accounts for 75.6 percent of total freshwater withdrawn [11]. The main sources of fresh water are lakes, reservoirs and rivers. They are typically replenished by precipitation; troubles arise when the rate of consumption outpaces this replenishment, potentially exhausting some sources of water in a worst case scenario.

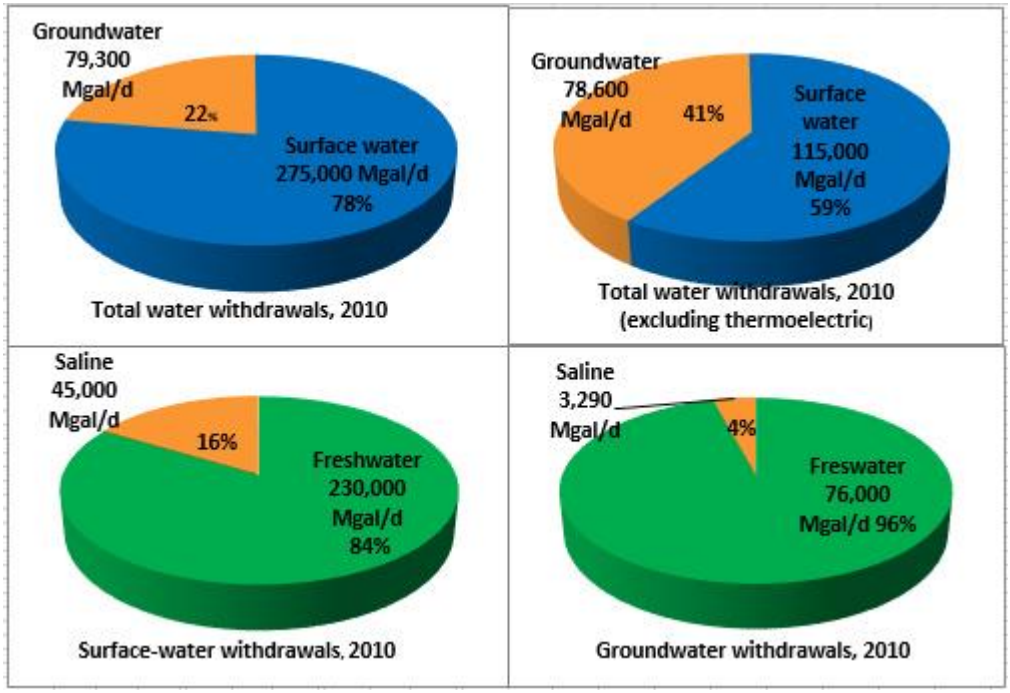

Figure 3: Surface and groundwater withdrawals of fresh and salinized water [11]

One of the main uses of fresh water today is agriculture, accounting for 70 percent of total freshwater consumption by people. The next largest consumer of fresh water is industry, accounting for 28 percent of total consumption. Finally, there is every day household water use that accounts for 8 percent of total consumption. Although it is difficult for an individual to affect the water consumption of agriculture and industry, people can still make educated decisions about what products to purchase. Although there is often a financial incentive to disregard industrial and agricultural water use, that decision carries more weight more impact than many of the changes an individual can make.

People do however have control over their own household water usage. Common household appliances that use water every day are found below:

Appliance	**Water Used (avg.)**
Toilets	5 gallons/flush
Showers	2.5 gallon/min
Sinks	2 gallon/min
Washing Machine	30 gallon/cycle
Dishwasher	6 gallon/cycle

Table 1: Water usage of household appliances [12] [13]

Now that is it clear how water is used on a daily basis, we can determine the proper advice to offer an individual to reduce water usage in various aspects of their life. Besides taking drastic measures such as growing their own food, they can choose to purchase foods that are produced more sustainably. For example, crops produced using drip irrigation can use up to 80 percent less water for similar or even higher yields. There are also some crops that naturally need less water to grow, and can potentially can be grown using dry farming practices in which crops are not irrigated and instead rely on soil moisture. Additionally, some farmers build their own reservoirs to capture and store rainfall for watering crops which can drastically reduce their water consumption from municipal water or wells. Although most farms do not implement these methods, one could purchase their food from specific farms that do, reducing their own water usage footprint as well as promoting these farms and their practices.

Despite household water use accounting for only 8 percent of all freshwater use, this is 8 percent that can and should be reduced, especially as agriculture and industry are also improving their water efficiency and reducing their usage. One way this can be accomplished is by replacing household appliances with more modern, efficient ones. Below is a demonstration of the potential water saved by doing so:

Appliance	Water Used (avg.)	Water Used (Improved)
Toilets	5 gallons/flush	<1.28 gallons/flush
Showers	2.5 gallon/min	<2 gallons/min
Sinks	2 gallon/min	2 gallons/min
Washing Machine	30 gallon/cycle	<27 gallons/cycle
Dishwasher	6 gallon/cycle	<4 gallons/cycle

Table 2: Typical appliance water use juxtaposed with more efficient appliance water use.

For many of these appliances, replacement with an improved product is only one facet of reducing water use. For example, individuals should limit shower time as well as turning sinks off when they are not directly being used. Washing machines should also be used at as close to maximum capacity as possible.

2.3 Paper Products

Trees are integral parts of human life. Not only do they reduce the carbon dioxide in the atmosphere, they replace it with the oxygen required by all fauna found on the planet. Additionally, wood is an incredibly versatile resource that is also renewable. Although there is a stigma against paper as environmentally harmful, current US forest statistics say otherwise. There have never been more trees than there are now in the continent. Additionally, the consumption of trees is less than the amount planted per year, though the number of trees that reach maturity are unknown [14]. The use of trees around the globe vary, but roughly 46 percent are used for fuel/energy, 43 percent is used to make paper/non-lumber products, and 11 percent is used as lumber for construction or woodworking [15]. Because the US is a developed nation, wood is used very minimally in the form of charcoal or firewood; most people have other methods of heating their house, usually though electricity or gas. Additionally, most families do not consume very many lumber products regularly, besides wood furniture. For these reasons, the focus of urban sustainability is centered on paper, the major wood product that people interact with daily.

Despite this evidence suggesting paper is the optimal product for wherever is it applicable, there are important drawbacks to using paper over other materials. Firstly, the wood that is cut down is replaceable, but the woodland creatures and other flora that previously inhabited it are not. While having tree farms does remedy this issue to an extent, there are still natural woodlands being cut down for the production of paper. Secondly, making paper requires

around 7.8 to 32.9 kilowatt-hours per kilogram [16]. To put this number in perspective, paper takes more energy to produce than most metals (aluminum, iron, steel) and glass, but still less than plastic. However, the fact that many plastic objects are lightweight in nature (furniture, bags, etc.) typically mean they require less energy to produce than their paper counterparts.

The United States uses 485 pounds of paper per capita per year. In contrast, Europe as a whole uses about 273 pounds of paper per capita per year [17]. Much of this is consumed every day to print or write things, with 100 sheets of 11" x 8.5" paper weight around a pound. Another common use is for toilet paper, or paper towels that weigh 8 ounces and 10 ounces respectively. Cardboard boxes can weigh anywhere from 3 ounces to more than a pound. A good way to reduce the amount of paper used is to go "paperless", receiving electronic documents in place of paper ones wherever possible.

2.4 Plastics

Plastics are the world's most versatile material, found in a wide variety of household items. The US consumes 68 kilograms of the most common plastics, polyethylene, polypropylene and polyvinyl chloride per capita per year. Europe consumes about 50 kilograms, showing there is much room for improvement [18]. The reason they are a sustainability issue is because of the way they are created and disposed of. Monomers, the building blocks of most plastics, are almost always synthesized from fossil fuels. Due to the unsustainable nature of fossil fuels, which is expanded upon in the next section, one can assume plastics are also not sustainable. Additionally, plastic items take centuries to naturally decompose, as shown in the table below:

Item	Time taken for decomposition (Years)
Plastic bottles	450
Foam Cups	50
Plastic Bag	10-20

Table 3: Average decomposition time for plastic items [19].

While plastics are decomposing, there are many ways in which they can harm the environment. If they are consumed by animals, they can poison them and/or clog their stomachs. Additionally, they can cause physical harm to animals that are tangled up in plastics or pierced by them. A commonly overlooked issue is that they can carry a wide variety of organisms over long distances, such as across an ocean, potentially introducing alien species

wherever they stop. When plastics decompose, they release the chemicals used in their production, polluting the water that it runs off to it is not properly disposed of in a landfill [30].

Some of the best ways to avoid generating excessive amounts of plastic waste is to not use single use items, such as plates, cups, forks, bags, bottles and others. However, because many plastics used in reusable and essential items, it is difficult to completely cut plastics out of one's life because there are no better options: for example, a plastic box for storage is lighter and easier to handle than their wooden or steel alternatives, and are also stronger than cardboard.

2.5 Fossil Fuels

One of the primary sources of energy in the US is fossil fuels. Coal and natural gas account for 33 percent of all electricity produced in the US each, with petroleum and other gases accounting for less than 2 percent of this value together [20]. While the ease of use and efficiency of these fuels make them desirable, there is a finite amount of these resources in the world. Gasoline has an estimated 30-40 years of use remaining, natural gas has around 60 years, and coal has around 200 years left [21]. Clearly humans need to find other sustainable sources of energy in the coming years, but for now, there is no getting around our need for fossil fuels.

Individuals typically have very little control over where their electricity comes from. Electricity is typically purchased from a middleman such as National Grid. These middlemen purchase energy at their own discretion. It could come from a coal power plant, or a renewable source, such as nuclear power, solar, or hydroelectric. The consumer has no say in the matter. However, if they were to purchase appliances that ran solely on one resource, such as natural gas, they could focus their consumption of resources to one fossil fuel over another. Solar panels would also potentially reduce electricity costs and guarantee that the energy produced is sustainable, though the startup costs are initially high and solar panels do not seem to be as effective during the night.

Besides being used to provide electricity for houses, fossil fuels are often used for transportation. The vast majority of motor vehicles on the road use gasoline as their primary fuel. For this reason, using public transportation or gasoline-free methods of transportation such as bicycling can greatly reduce an individual's gas consumption. Riding a bus filled to 100 percent capacity averages around 330 passenger miles per gallon, as buses average 6.1 miles per gallon and typically hold a maximum of around 55 people [22]. If one has the money for it, they could also consider purchasing electric or hybrid vehicles. Although less gasoline is directly used in driving the cars, the electricity used to power the cars potentially could still be coming from fossil fuels. Because it is so hard to directly limit the amount of gas being consumed as an individual, regulation of energy consumption as a whole is often the best option.

In order to minimize impact, it is important to understand where electricity comes from. For example, purchasing an electric car in a town that gets its electricity via coal power plant might not be as environmentally friendly as one would be lead to believe. Being aware of one's location and making responsible decisions with that information is critical to being sustainable.

2.6 Recycling

There are many common household items that can be recycled if they are not contaminated. These items include metals, paper products, glass, plastics, electronics, batteries, and bulbs. This allows for conservation of virgin materials in nature as well as preventing these items from ending up in a landfill in an unrecoverable state. Some states and countries make the recycling of some materials mandatory due to their toxic nature [23]. There are also many other sustainability-related motivations for recycling.

For metals, the mining process both uses a lot of energy and is taxing on the environment. Some of mining requires clearing of the land above it, destroying forests and habitats. Almost all forms release other more toxic or undesirable chemicals that they were not mining for into the environment, such as mercury or cyanide [24]. This harms the local wildlife and pollutes the local groundwater and air. Additionally, underground mining forms voids in the earth that are prone to collapse, potentially representing a hazard if structures were to be built over it [25]. Besides environmental concerns, recycling metals saves much more energy than production from virgin resources, as shown in the table below for many common metals:

Material	**Energy saved using recycled materials**
Aluminum	95%
Copper	85%
Lead	65%
Steel	62-74%
Zinc	60%

Table 4: Energy savings for certain materials from recycling [26].

Similarly, recycling paper saves both energy and resources due to avoiding the process of converting trees into the components of paper. This results in less forests and habitats being destroyed for their wood. Similarly, the carbon released during paper production using virgin resources is prevented [26].

Glass is a unique material in that it is 100 percent recyclable; one glass bottle can be melted down and turned into another without any additives. Additionally, for every 10 percent of a glass object that is made of recyclable materials, there is a 2 to 3 percent reduction in energy costs [27]. Due to the fact that glass can take millions of years to naturally decompose [19], recycling is the optimal method for keeping it out of the environment.

Many issues with plastics that are not recycled are mentioned in the Plastics section. Other reasons to recycle include energy savings, as is the case with most recyclable materials [28].

Recycling electronics allows for the recovery of many rare earth metals that were used in their production. Recovering the metals this way is much more efficient than mining them out of the ground, especially as they become more and more difficult to find. Electronics that go to landfills are also incredible toxic; they account for 2 percent of total landfill space, but 70 percent of the toxic waste that is present there [29].

Recycling batteries and light bulbs prevent many of the potentially toxic chemicals stored inside from entering landfills, and are instead extracted for other uses. Battery shells can in turn be remade into batteries or other metal products [30], while just about every piece of a light bulb can be separated and melted down for other uses [31].

2.7 Pollution

The areas of pollution that pose the greatest threats to sustainability are air, water and soil pollution. The other forms of pollution, including light, noise, visual and thermal, do not have as great of an influence on sustainability or are difficult for an individual to interact with, and are not discussed in this proposal.

One of the most direct effects of air pollution is felt by humans living in polluted areas who suffer respiratory diseases as a result of the pollution. Pollution is known to cause or exacerbate other diseases as well, such as cancer and pneumonia respectively [32]. Another result of air pollution are several ecological disasters, one of which is global warming. Not only is it destroying habitats for organisms around the world, but it is depleting the polar ice caps, a potential source of fresh water. Other disasters include acid rain and depletion of the ozone layer. Both can cause environmental and property damage in cities and habitats. Lowered planetary resistance to UV rays also puts individuals at risk for various skin and eye problems. This pollution comes from many sources, including factories, agriculture, and the burning of fossil fuels. The ways an individual can limit their contribution is mostly through conservative measures: use public transportation as often as possible, do not purchase unnecessary goods and recycle often. Additionally, because electricity is typically produced to some extent by burning fossil fuels, conservation in that regard is important as well [33].

Water and soil pollution are also somewhat tied to air pollution. When particulates accumulate in the air, they often return to the earth when it rains, and the chemicals present runoff and collect in bodies of running or still water or accumulate in the ground. Other sources of pollution include waste water, sewage and chemical pollution [34]. There are many ways one can prevent this. Although water is typically treated before it goes from a reservoir or lake to one's house or vice versa, there are many chemicals that the process is unable to remove. For that reason, it is advisable to not dump pills or other drugs down your toilet or sink. Additionally, one should be careful with what other chemicals they allow to run off into drains, such as car antifreeze or paint products [32]. Even fertilizer should be applied sparingly;

the nitrogen rich runoff promotes excessive plant growth, such as algal blooms, and aggravates pest problems [33]. Finally, toxic chemicals that are dumped in one's yard will disperse into the local water table as well as the soil, but will not break down. If this is done infrequently the results will be unnoticeable, but should the chemicals accumulate, the water extracted from beneath the ground could become unusable.

2.8 Electricity

In the US, the majority of the electricity is produced from the burning of fossil fuels. Coal and natural gas each account for slightly more than 33 percent of the nation's total energy, nuclear power accounts for 20 percent, hydroelectric power contributes 6 percent, other renewable energy sources account for approximately 7 percent, petroleum and other gases account for less than 2 percent [20]. Although an individual may obtain energy in different proportions than the national average depending on location, fossil fuels will inevitably be tied to electricity in America today.

A significant consumer of energy in many households is the refrigerator, on average using 12.7% of total energy household energy consumption [35]. With most appliances one can save energy by using them less and unplugging them, but that is not practical with a refrigerator. The main way to save energy with a fridge is to use an efficient model. New fridges are much more efficient than older ones. In many households in Worcester, people use older models of refrigerators. For example, a 1986-era 18 c.f. fridge uses 1400 kWh a year, while a modern energy-efficient model uses only 350 kWh — a whopping 75% reduction [35]. At 15¢/kWh, trading in a pre-1986 fridge for a new efficient one would save about $158 a year in electricity costs [35]. But the amount of money saved could be as high as 240$ [35] if the modern refrigerator is used optimally. By paying more attention to the efficiency of one’s refrigerator, one can greatly reduce energy consumption

In many houses in warmer climates, air conditioners use the most electricity, taking up about 16% [36] of the total electrical consumption. In the warmest regions, AC can even account for 60-70% [36] of the electric bill over the summer indicating that this area of electricity could yield the highest percentage of monetary and electrical savings if acted upon. Generally, AC usage should be limited as much as possible, and when it must be used, the setting reasonably low. Each degree that a household is cooled will increase energy costs up to 3-4% [36]. A more sustainable option would be to install ceiling fans if circulation is the problem and not temperature as they are far more energy efficient than AC units. They cost about $40 [36], but it would save a lot energy and are far cheaper than ACs. (A typical 36" / 48" / 52" ceiling fan uses about 55 / 75 / 90 watts of electricity respectively at the top speed.) Central ACs costs up to 70 times more to run than a fan. [36]

Regarding lighting efficiency, many individuals do not pay attention to what bulbs they put in their light fixtures. However, using new LED or CFL lights could save 70-90% of lighting energy compared to fluorescent bulbs [37]. The correct and safe use of CFLs or LEDs can yield a large reduction in energy consumption, while being a relatively easy change to implement.

watt(w)	Numbers of bulbs	Hours on per day	Standard lights	CFL	LED
40	4	4	$214	$57	$46
60	4	4	$288	$80	$53
75	4	4	$358	$106	$100
100	4	4	$497	$123	$111
Total cost			$1357	$366	$310

Table 5: Cost of different lights over 5 years [37].

From Table 5, we can see how using LEDs or CFLs can save money over time. By using LEDs or CFLs, we use only 24% of the energy used with standard lights. We can save up to $1000 every five years. This table only shows the possible monetary yields with 4 bulbs being changed to LED or CFL, but if all the bulbs in a household were to be changed there could be an increase in savings from $1000 in five years to potentially $5000 in five years [37]. These small changes can yield large increases in personal sustainability both for the environment and for personal finances of an individual.

2.9 Surveying Techniques

There are several factors to take into consideration when deciding how to collect the data needed to judge the level of sustainability of the lifestyle of an individual. Firstly, the survey process takes into account the goals, target population, timing, and mode of the survey [38]. Many of these aspects have already been determined; the goal is to improve the sustainability of the user and the target population is anybody living in an urban area. However, the timing and mode of the project will have to be determined by best judgment, and is described in the methodology. Once the process has been determined, the questions provided must possess two characteristics to be useful and meaningful; reliability and validity [38]. Reliability means that all users should interpret the question the same way. Validity means that the survey accurately measures what it is supposed to. Sample questions and explanations are provided in the methodology. Finally, a decision must be made as to how collected data must be handled [38]. Important questions to address are how will the collected data be stored, and how will it be

used to provide meaningful feedback for the user. Additionally, failure on the part of the user must be accounted for, such as not answering certain questions. However, it is likely that there are individuals that have no education or interest in the topic of sustainability, and wouldn't want to spend their time taking a survey on it. For this reason, we have to consider incentives to have people take the survey.

2.10 Related Applications and Web Sites

There are several applications that influence the design of this project. Firstly, Dr. Martin Burt provided a demonstration of his own Android survey that was designed by Hewlett Packard. It managed to quantify aspects of life that were difficult to measure by using pictures, and coupled with minimal text and a touch interface, offered a simple but effective way to survey an individual. It served as a powerful tool for both self-realization and improvement in the communities around Paraguay where it was implemented by Dr. Martin's foundation. Showing real promise as the first tool that not only gives numerical data on poverty, but personalizes it with a detailed plan for improvement and personal growth for the household. Secondly, the Qualtrics survey design program provided through WPI gives some insight into how a survey can be implemented on a digital interface [39]. It also allows for the implementation of questions before the application itself has been developed.

3. Overall Methodology

3.1 Introduction

One factor that cannot be ignored is all of the preexisting work done by other groups, such as carbon footprint calculators, or even just a comprehensive list of energy star appliances. This will impact every aspect of the project, from developing the definition of urban sustainability, to the application itself. When making design decisions, the definition of urban sustainability must always be considered as well.

This section will discuss the methods through which the the survey will be administered. Additionally, it will explain the methods through which the application will be developed as well as the optimal implementations of certain features.

3.1 Survey Administration

A crucial but often overlooked part of a survey is getting enough people to complete it for it to be relevant. The accessibility of a smartphone application will hopefully allow for better coverage of the general population. Initially, the test could be administered door to door to increase interest, and hopefully it will then spread by word of mouth. WPI students and faculty are also a good targets for examination. Awareness for the application will be raised through emails being sent to all students, posting on class Facebook pages, and through word of mouth from all group individuals in order to increase the number of participants. The time this test will be administered personally will be on weekends, to have a better chance at the user being available and giving thoughtful answers.

The initial data will come from a survey or evaluation with multiple questions, which the user will answer to the best of their ability, it will contain a good amount of questions to make sure the evaluation can capture enough desired information to accurately describe the user's urban sustainability habits. For example: how many times a day a user goes to the bathroom or brushes their teeth, and how many electrical devices the user has and has connected to their wall outlets on average. A more advanced and numerous set of questions can also be selected by the user to further describe their habits. Once the user has completed the questionnaire, they will be given a rating out of one hundred based on their performance, ranging from very well to very poor, which will be indicated through a red, yellow, or green indicator. These color ratings will correspond to a certain range on the 0-100 scale for example 0-50 would be red, 51-75 would be yellow, and 76-100 would be green. If enough people are able to take the exam, the user can also be scored in reference to other users, displaying what percent of users they scored better or worse than.

3.2 Preliminary software design

The application contains questions that relate to all chosen facets of sustainability, such as water and electricity, in order to accurately evaluate the user's urban sustainability habits. Developing a method to empirically evaluate users in terms of their sustainability is critical to the success of this project as it is integral to both the survey and application. A weighted average system come across as a reasonable solution to the problem; for example, it allows for an individual's fossil fuel use to have a more significant impact in the evaluation than their water use. The dimensions of sustainability would become the initial categories, each having a weight associated with it. The dimension weights will total to 100, similarly to many grading systems. Each dimension's respective grade is calculated in the same manner as the final grade, however using that dimension's subcategories as opposed to the dimensions themselves. Ultimately, each node in the sustainability tree is either a grade itself, or a basic value as far from the root (the final grade) as possible. While this was a good principle, it requires every topic to have a weight associated with it, which will be difficult for something so complex as sustainability.

The application will collect data through slider switches or radio buttons that the user can interact with on the touch screen of their phone. Examples of these questions would be how much electricity or water the house consumes a month/year. This type of numeric data would yield best results if there could be an exact input given instead of a picture with various ranges of options.

3.3 Implementation of Software

We are using an iterative design process to complete this project, both in terms of software development and this project in general, this means that at any given point in time, there is (or should be) a "working" version of the project. This is done in software development by initially creating a basic shell, and expanding it one element at a time. This technique allows for a record of all previous working prototypes, and therefore there is always a working fallback in case something goes wrong. The Poverty Spotlight application could be used as the initial working model, as it has similar features to those of the Sustainability Spotlight, and should have a preexisting framework that can be used when design other aspects of the application. This concept also works its way into our overall project in the form of the projected user space for the project.

3.4 Data Analysis and Recommendation Techniques

Once responses have been received from the surveyed individuals, there are many things to take into account regarding the processing of this input. One such aspect is the financial situation of an individual, as many of the solutions that will be presented have a premium cost associated with them, such as buying organic food. However, many solutions also will save

money, such as LED lights, which will immediately make a positive impact. While refrigerators or solar panels are a larger investment, the money saved is also greater. Understanding that not all changes can be made is not only an important part of the improvement process, but also must be considered when giving a family a grade, as while empirically two families could have the same impact a family with more financial means could perhaps make more changes without putting their socio-economic status at risk. and therefore that decision should be part of the evaluation calculations.

Consider a situation where family A does not have any LED lights in the house, but standard lights instead. The application will include the table to ask the users why they do not have the LED lights and then analyze various reasons as to why they do not have LED lights such as financial or awareness reasons. Through these reasons we can get a better idea of how to improve sustainability for a household. This can be done by identifying the cause for the household not owning LED lights and then acting on that reason. For example a household does not have LED lights because they didn't know about them, so we can start teaching sustainability to the household in order for them to see the importance of their choices. The solutions in the table will help them find out a plan so that each person in the house could potentially save money every day by reducing small purchases such as a soda. This would eventually add up over time allowing for the household to afford LED lights if there is a financial reason for not having LEDs. That is how we can come up with the solutions for helping people become more sustainable in their life. This demonstrates an effective strategy for allowing people to see in which ways they can improve their sustainability, while also being able to recommend paths for them to reach these sustainability goals and changes if they are currently out of reach for the household.

The application will focus on areas the user is deficient in as opposed to not having a focus, as more impact can be made. For example, if the user answers the survey and through all the water questions answered it is found that they use on average 65 gallons of water per day then we would compare them to our metric. This could be compared to the average water consumption of a in Massachusetts resident, which is 57 gallons. Thus, the application would make it clear to the user that they are likely using too much water and provide tips and resources helping the user live more sustainably. On the other hand, If the user's answers indicated that they use somewhere between 0.5-1 pound of paper per day, then they would fall under the national average of 485 pounds per year. Therefore the application would not hide this information, but instead of advertising paper sustainability, the information about water would more exposed to this specific user. Additionally, many individuals could either be too busy or uncertain about certain questions on the application, so the application should always help users improve regardless of the completeness of the survey. These are just some examples of the application’s methods to identify the user’s sustainability levels and how the application will identify if and how much improvement can be made for the specific user for all aspects of sustainability created through our indicators. These comparisons to local, state, and national

averages will be simple at the Worcester level and will become increasingly more difficult as the scale of the survey increases.

Evaluating WPI students will be different than an average household due to their living situation. They either live on or off campus, or commute. Commuting students, while potentially the least sustainable, likely live in a more traditional manner. On the other hand, both dorm life and renting make evaluating the user much more difficult. Those that live in the dorms have zero choice regarding most appliances with the exception of perhaps a mini-fridge, some lamps and a fan. Furthermore, each individual often has roommates that would make collecting usage data more difficult. Finally, most users would likely not be able to even find that data in the first place. Other students that rent apartments also have their difficulties. While they too often have no control over the major appliances they have, these appliances are likely not efficient or even recently made, as the landlord does not pay for the inefficiencies, the tenants do. Furthermore, students do not live in at college for all months of the year, which likely causes wasted heat and electricity at the minimum.

4 Qualtrics Survey

4.1 Survey Design

The initial Qualtrics survey was created to gauge the quality of questions created for the application. The survey was to test the wording of the questions for neutral and non-leading/loaded questions in order to ensure that we received unbiased responses. The recommendations for questions that were tested had to be easily acted upon by WPI students as this was our preliminary target audience meaning that questions were focused on daily tasks and habits that a student could change and have an easy influence over. There are some factors that students cannot change without going through WPI facilities and therefore we avoided asking questions related to these issues. To identify whether or not this was influential we placed bias indicating questions at the end of the survey to gauge the responder's general opinions and involvement with sustainability or green movements.

The survey contained mainly multiple choice questions with a few slider questions and a comments, questions, and concerns section at the end of the survey for general feedback. The questions chosen were simple and did not require much time spent in order to get accurate answers, but there will be more complicated and involved questions on the final application. For example, we asked how often a dishwasher was used in the Qualtrics survey, but on the final application there will be a question asking for more information such as make and model or if there is an energy efficient mode. This level of depth could not be included in order to maximize the time spent on the survey to information gained ratio as well as increase the number of responses received.

The survey also had to be very straightforward in the questions in order to remove any vagueness for the responder. Additionally, by asking direct questions such as how many times

they showered, reused water bottles, or recycled we hoped to have users become more conscious of their actions, thus increasing their own awareness of sustainability. If a question is too vague it makes it harder for an individual to reflect on their answers on the Qualtrics Survey. This will be easy to deal with in the final application through the tips section, so asking what year is the dishwasher they are using does not give the user any insight into their sustainability levels. Instead, we asked questions about how or when they use their dishwasher instead. To further instill this pattern of self-reflection, we eliminated questions that needed an input field that the user needed to fill out. This is due to the fact that these usually take more time to answer than if they are given a slider or multiple choices as well as fill in answers tend to be left blank out of any answer choice due to the added level of effort.

The fundamental idea of the recommendation is to provide research and statistics to the user based on their answers to the questions in order to convince/show them the positive results they could receive from changing their habits as well as to make it clear exactly what to do to improve their level of sustainability. This makes it easier to convince an audience who may not care to change their actions as it shows them expected tangibles from improving sustainability such as a decrease in utility bills. Having a user realize the monetary gain and environmental protection involvement they could attain through small actions will serve as a strong call to action, which is ultimately the goal of the application.

4.2 Question Selection

For the Qualtrics survey, the questions were chosen specifically for the WPI student community. We wanted these questions to be both relatable and actionable for the average WPI student in order to have these questions be meaningful for the user. It was difficult to select 15 sustainability questions out of the 70+ questions that were originally written for the application due to the goal of optimizing information gained, actionable results, and shortness of the survey.

The first and third questions were targeted towards daily habits of showering in order to get a general view on the use of water for the respondent. While there are far more uses of water in daily life, such as water used for running water, food, lawn maintenance, and drinking, showering is the easiest to effect for the student. Everyone who responded has the capability to lower the number of showers that are taken per day and how long those showers last. These questions are also very easy and quick to answer due to the fact that they are a daily habit optimizing how much information we gain on water use and the time the person invests to answer the questions accurately.

A lot of students who live on and off WPI campus have access to a dishwasher and use it frequently, so we wanted to get that information from respondents. Most students do not have the money or ability to change their dishwasher to a more efficient and newer model, but they can change the way they use their dishwasher. This allows us to get another attribute of how water is being used by our user that is once again simple and quick to answer while allowing us to get a good insight into water use for the user. These three questions together create a limited, but

important view of how water is used for the respondent that we can make direct information on how and why to change their daily habits.

Recycling is a prevalent issue to most students as there are signs and reminders for greener habits all around campuses and universities. To see how these recycling habits, we asked a few questions such as how paper products are disposed, what type of utensils are being used, how many plastic bottles are used, are reusable bags being used, do you use paper towels, and how well does the individual know about recycling. These questions all form a view on recycling and waste habits from the respondent that we can affect easily and quickly with minor changes in daily living. In addition, these questions are very actionable as all of them deal with small daily habits from wiping up messes to buying a plastic water bottle for lunch. All of these questions have tiny answers that stacked up over time and over numerous users apply them. If our users wipe up their messed with reusable wipes more often and invest in a long-term water bottles for their water at lunch, there will be a significant amount of paper towels and plastic bottles that don't go to landfills or towards hurting the environment.

The next series of questions that were asked were to gauge the user's consumption of electricity. We primarily asked questions on figuring out if the user had any habits of wasting electricity through forgetfulness or not knowing they are even wasting electricity. The questions asking if the user is leaving chargers plugged in, leaving lights/electronics on overnight, or if lights are left on overnight is aimed at gathering how much electricity the user is wasting without any real purpose. These questions serve a purpose in simply asking them by allowing the respondent to think about these small problems that they could fix very quickly in their personal lives. The other questions such as AC use allow the user to gauge if the way they are using their electricity is optimized or if they can reduce use in order to reduce their electricity costs. All of these questions also allow for incentivizing reducing energy use in order to save money, which is enticing for most students across the globe.

Finally, the last five questions were placed into the survey to gauge the general biases and opinions on sustainability from our respondents. We expected a strong bias towards being more sustainable and trying to be greener as our audience was WPI students who for the most part care about the environment and are educated on pressing issues that the earth is facing. In addition the current generation has a larger amount of people who are more environmentally aware and concerned for the future. These questions generally asked if the user works on anything based around sustainability in their free time to gauge how important sustainability was for the users. We also tested the percentage of Apple and Android users to see how popular our application would be and how many people could use it, as these are two independent variables, because our application is written for Android products.

The final question is simply the gauge the audience on the overall survey and see any insights and recommendations that could be made to improve our application. There was useful feedback that has been taken and introduced into the application already and there were other responses that were implemented, but noted with the team as a potential idea. There was a lot of positive feedback on the actually application that is going to be launched from this general

comments section showing a want for our application, while the rest of the questions showed us the need for our application.

5. Results and Discussion

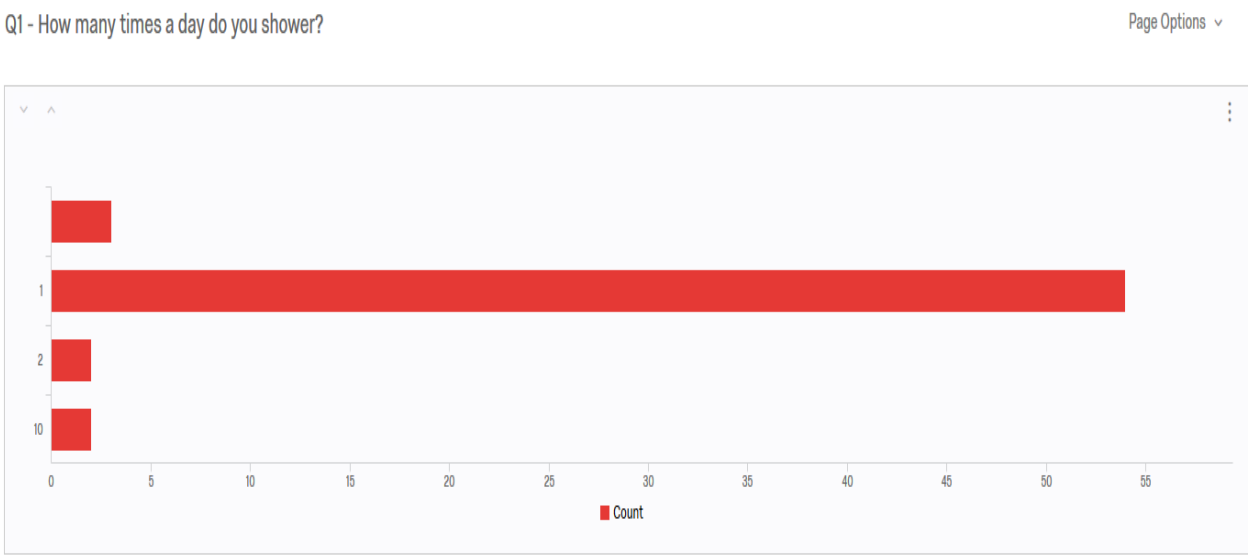

Figure 4: Q1 responses

Based upon the data that we collected in the Qualtrics survey, we could see most responders took a shower once time every day on average. We consider taking a shower only one time a day is ideal for saving the amount of water usage. By limiting the number of showers a day, one could save both water and money.

The next dimension of interest is paper sustainability and how people deal with the paper that they no longer use. Many individuals have a recycling service available at home, and can easily dispose of recycling waste. Despite this, some people disregard this option and throw recyclables in the trash.

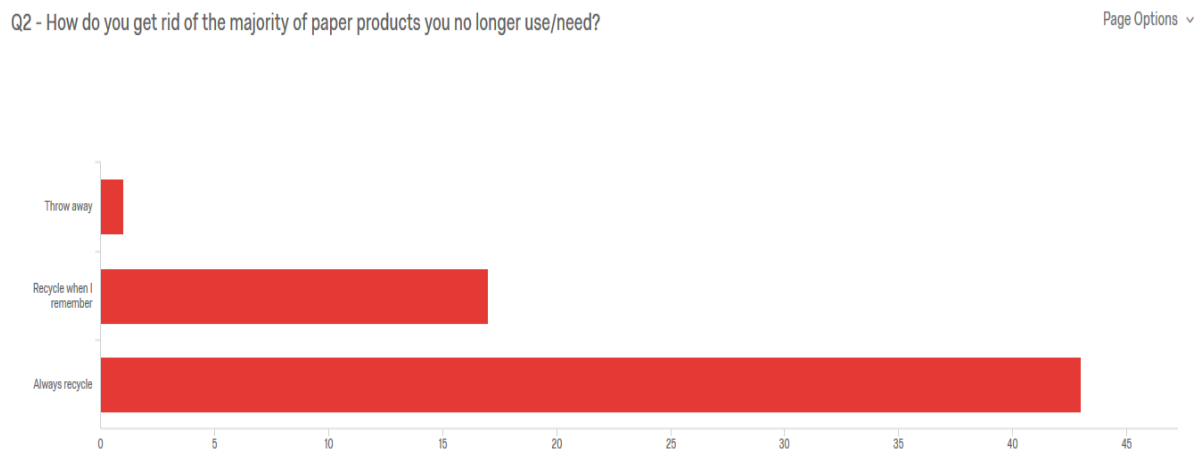

Figure 6: Q2 responses

We had 60 responses in total for this question. About 70% responders remember to recycle their used paper. About 28% people recycle whenever they remember and the remaining 2% people never recycle.

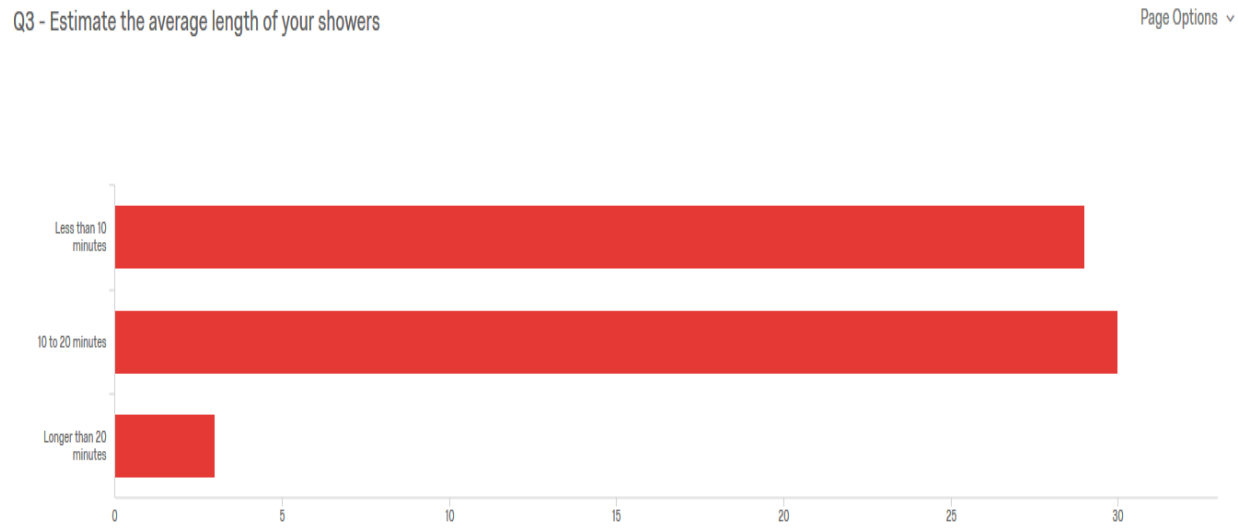

Figure 7: Q3 responses

Based upon the data that we collected in 60 responses, we could see most people average one shower a day. We consider that taking a shower only once time a day is a good number for saving the amount of water usage. By limiting the number of showers a day, one could save both water and money.

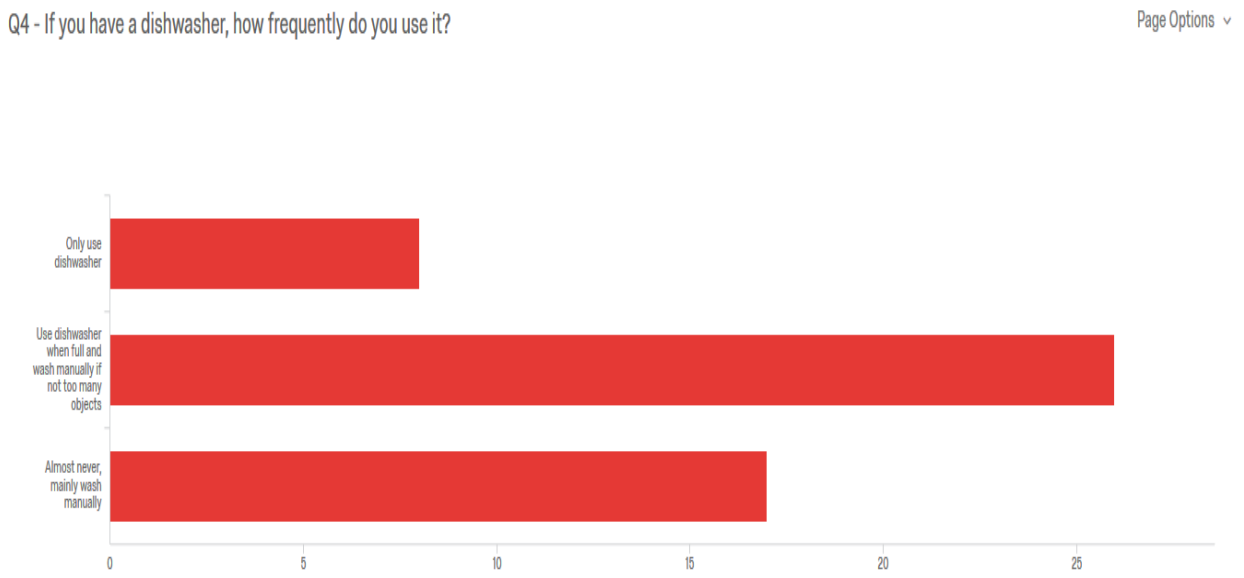

Figure 8: Q4 responses

Out of a total of 50 responders, 16% use a dishwasher, 51% people use the dishwasher when necessary, and about 33% people wash the objects by hands manually. Overall, the responders that wash dishes by hand are encouraged to use dishwashers if they already have one. Doing so would reduce water consumption and save money on average.

Nowadays, more people have a dishwasher in the house. A more modern dishwasher uses only half the energy, one-sixth of the water, and less soap than an older model. There is some argument in terms of efficiency for using dishwashers or washing dishes manually. The more efficient choice is dependent on the situation because if you have more dishes that need to be washed it is more efficient to use a dishwasher. However, if there are not many dishes to wash, then hand washing them can save energy and water.

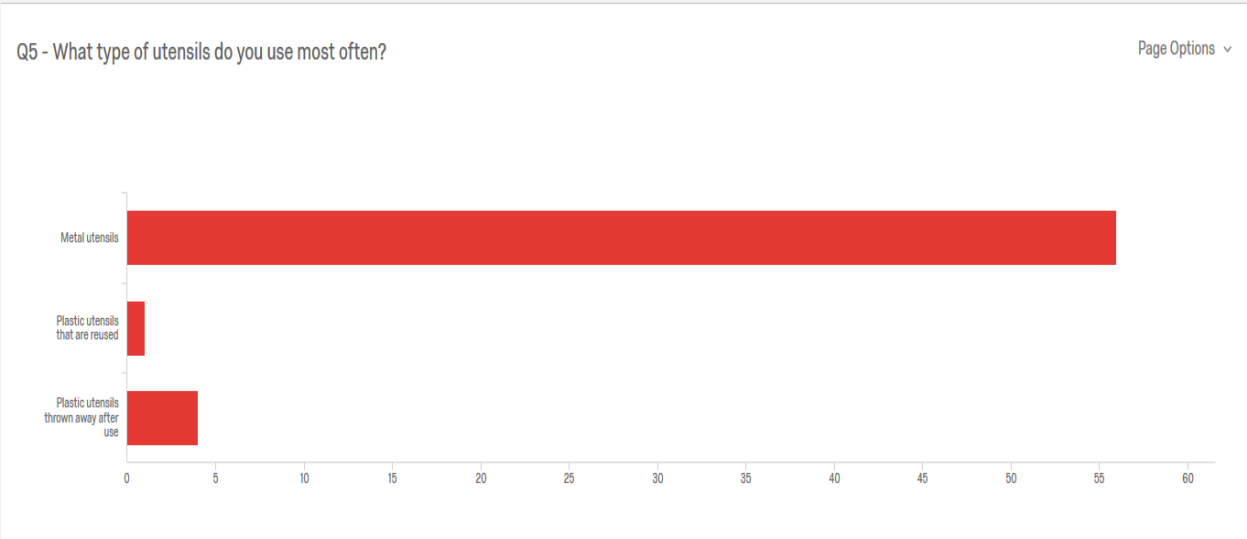

Figure 9: Q5 responses

We collected 60 responses from this question. About 92% of responders used metal utensils. 2% people used plastic items which can be reused and 6% people use plastic items that are thrown away after use.

Metal utensils are preferred because individuals can use and then reuse them for several lifetimes. With plastic utensils, the user constantly need to purchase more, and generates trash every time they dispose of their previous utensils.

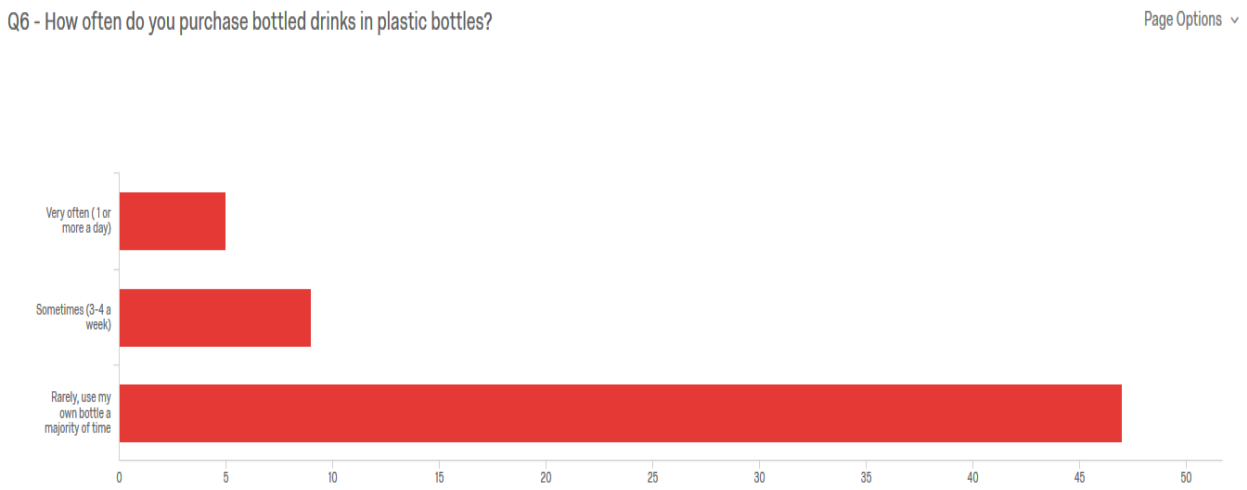

Figure 10: Q6 responses

There were 60 total responses for this question in which 77% responded that they use reusable water bottles and 23% people purchase the drinks by the bottle at varying frequencies.

Individuals are recommended to reduce their consumption of plastic bottles in order to reduce environmental pollution when they eventually need to be disposed of.

The next dimension of interest is electrical sustainability. The first question for this dimension asks the user how often they leave the lights on when they are not in the room.

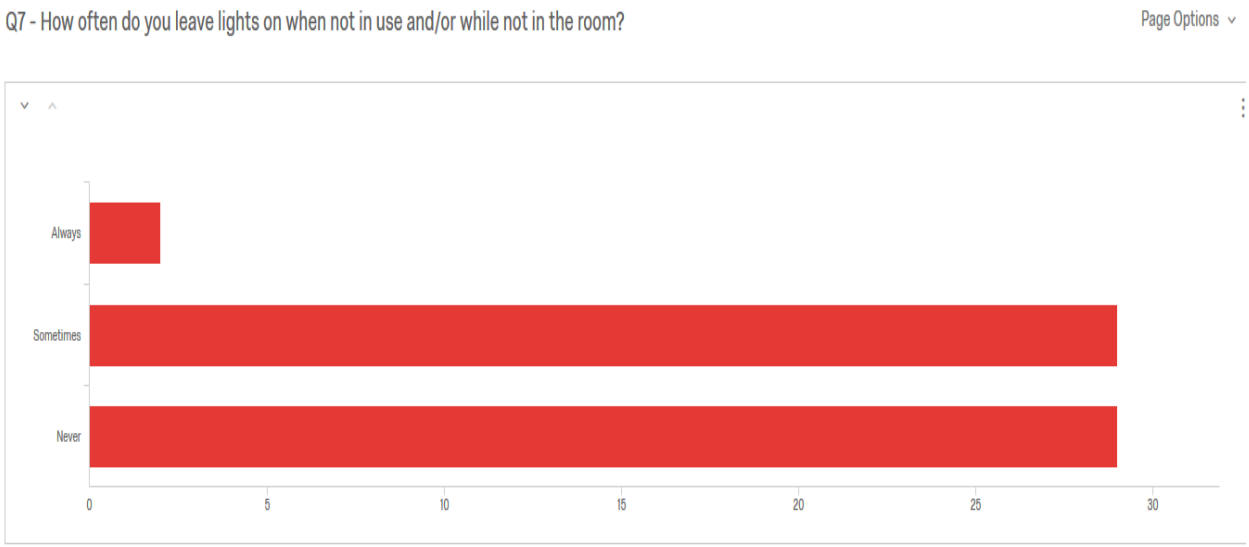

Figure 11: Q7 responses

We received 59 responses for this question. About 48% people always turn the lights off as they leave, 46% of people sometimes forget to turn the lights off and 6% always turn the lights off when they leave. For those that always forget to turn the lights off as they leave the house, the application offers some recommendations for them. One of these is to use lights that turn off automatically after a set amount of time as opposed to traditional light switches/fixtures.

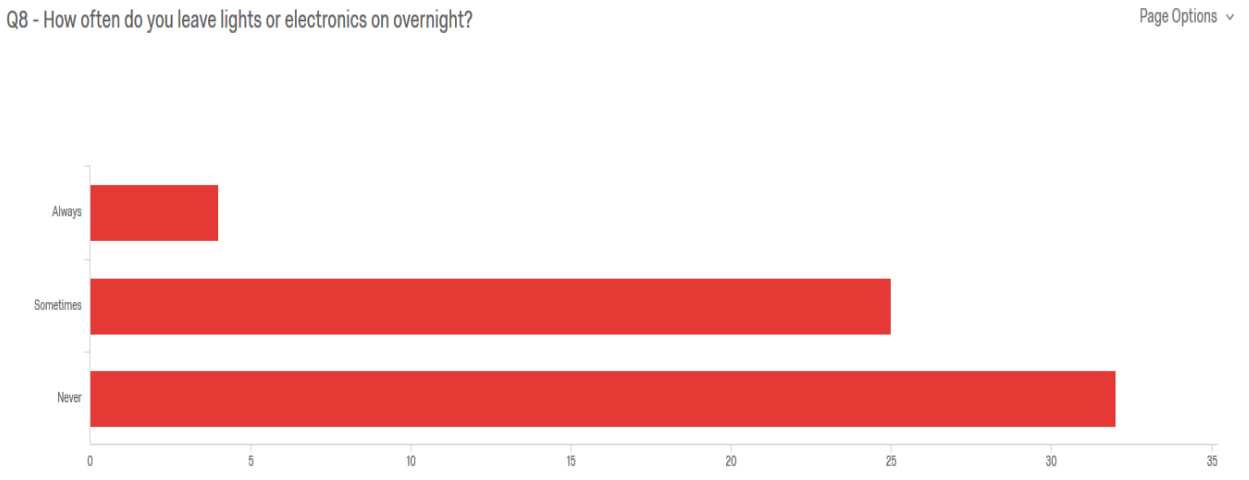

Figure 12: Q8 responses

We received 61 responses in total. About 7% responders always leave lights or electronics devices overnight, 41% people sometimes forget to turn off their lights or electronics, and 52% never do so.

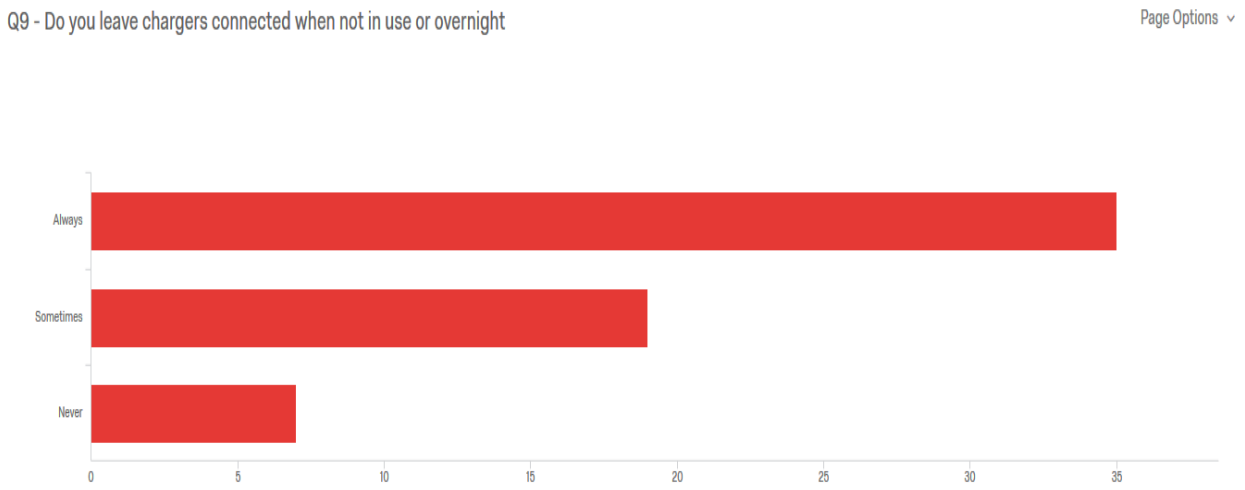

Figure 13: Q9 Responses

60% of individuals never unplug their chargers when they are not in use and leave it plug overnight. About 32% people sometimes unplug their chargers overnight, and 8% always disconnect their chargers overnight.

Another important question relating to electrical sustainability is the age of one's AC unit.

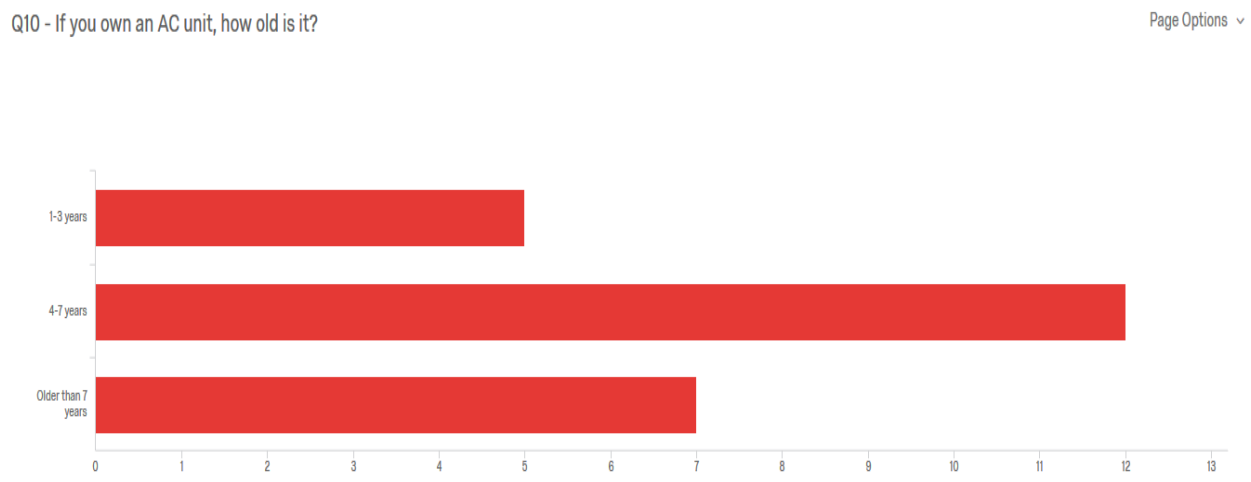

Figure 14: Q10 responses

For this question, we received only 24 response because some household do not use air conditioning. About 22% people own systems that are 1-3 years old, 47% people own systems that are between four and seven years old, and about 31% people have owned their system for longer than 7 years. The older systems typically consume more energy, which will cause an overall increase in electricity costs.

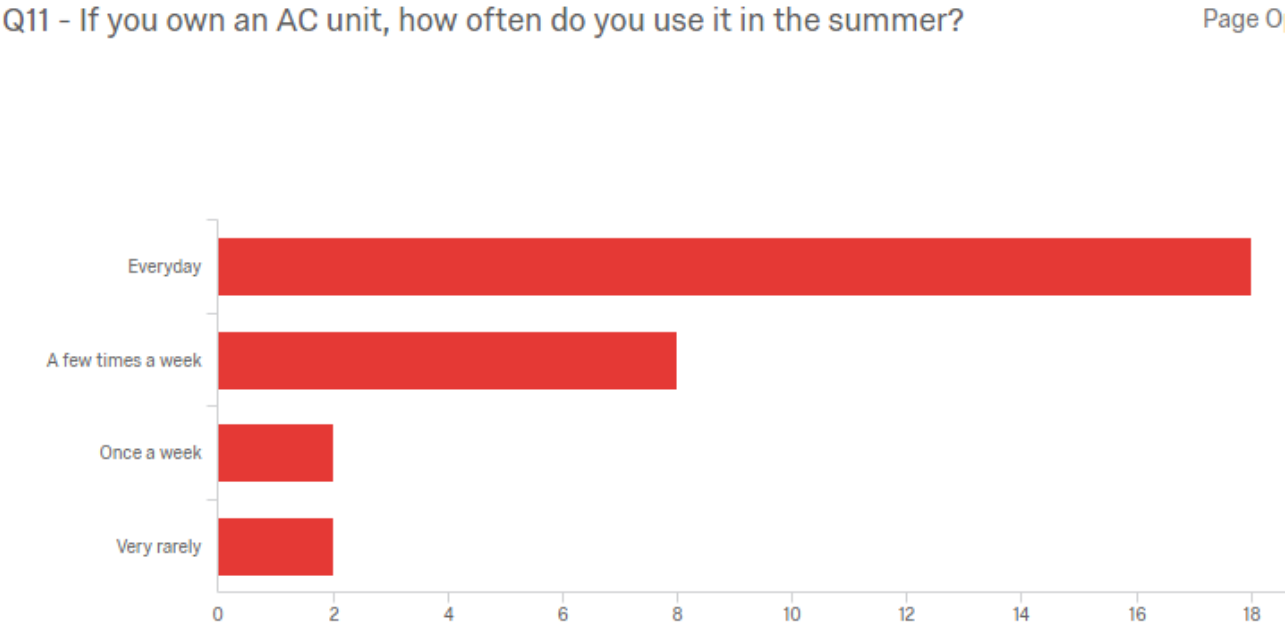

Figure 15: Q11 responses

We had 32 responses in total for this question. Again, this is largely due to some houses not having AC installed. About 60% of people use the AC every day in the summer, 27% of

people use only a few times in a week, and the remaining 23% of individuals do not use their AC very often.

The next category of interest is paper sustainability.

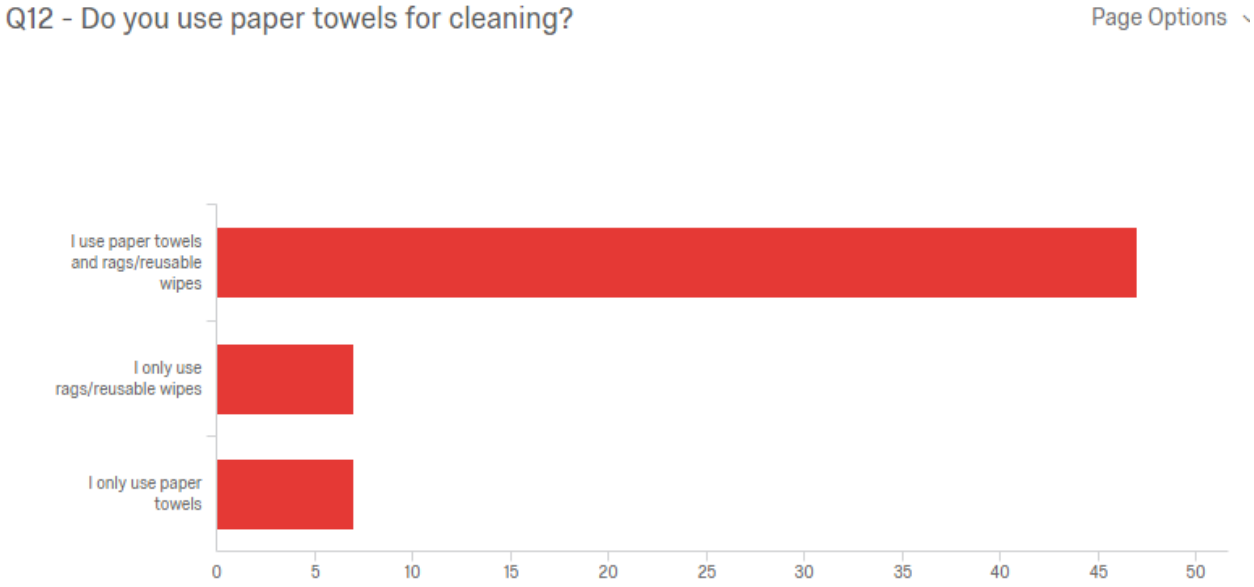

Figure 16: Q12 responses

We received 61 responses in total. About 77% people use rags or reusable wipes for cleaning which are expected to be. About 11.45% responders use the rag/reusable wipes and about 11.55% responders use the paper towels all the time. The graph tell us that the majority of people know how to save money on using these rags over the paper towels. By giving the suggestions alongside with the user's sustainability, we could expect more people use the rags.

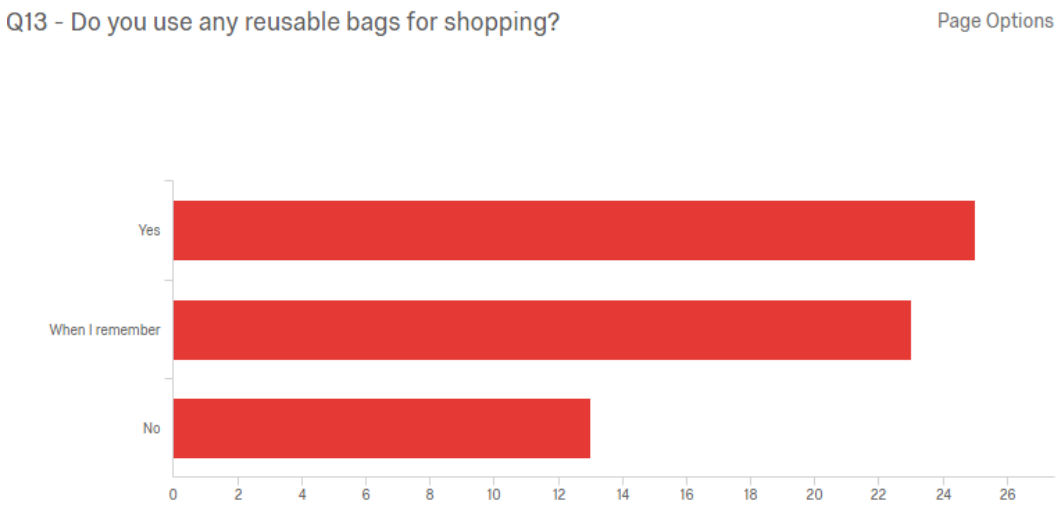

Figure 17: Q13 responses

61 responses were received in total. About 41% responders use reusable bags shop, about 38% responders use the reusable whenever they remember, and 21% responders never use the the reusable bags when they shop. The 21% responders that never use reusable bags are considered the poorest performers in this category. Hopefully, after implementing the suggestions offered in the application, we can expect to see more people using reusable bags instead of whatever the local store offers.

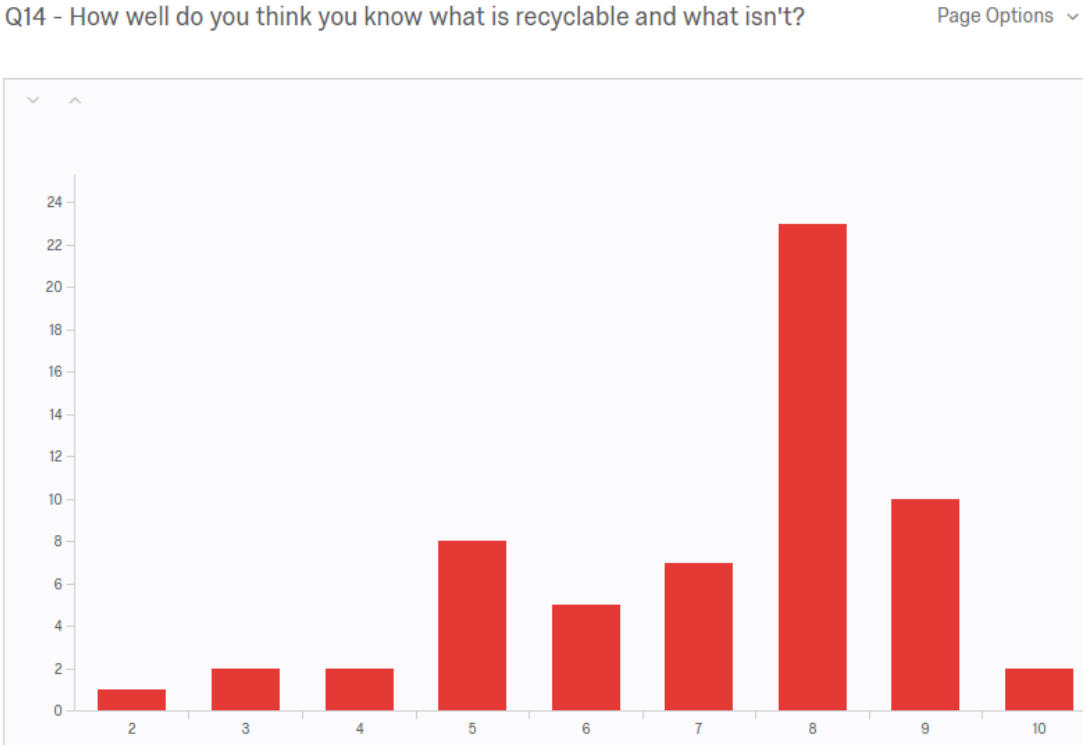

Figure 18: Q14 responses

We scale from 0 to 10 which increases in the intensity of understanding about the recycling. Overall, most users seemed to think that they have a good understanding of what is recyclable and what is not.

The next questions were not present in the application, but were included in the Qualtrics survey in order to determine how interested people were in sustainability.

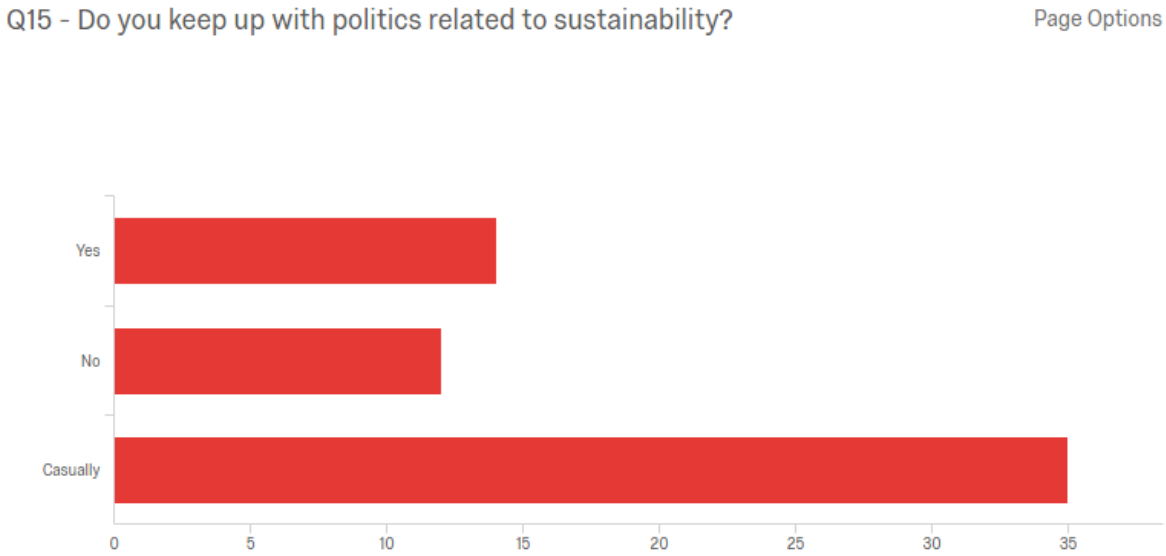

Figure 19: Q15 responses

We received 61 responses in total. About 23% respondents said they kept up with the politics related to the sustainability, 20% don't keep up with politics and the remaining 57% are somewhere in between.

Figure 20: Q16 responses

We received 60 responses in total. There is undeniably some amount of response bias here, as most individuals who took this survey in the first place did so out of a personal interest in sustainability. Regardless, it is interesting to note that so many people value sustainability so highly.

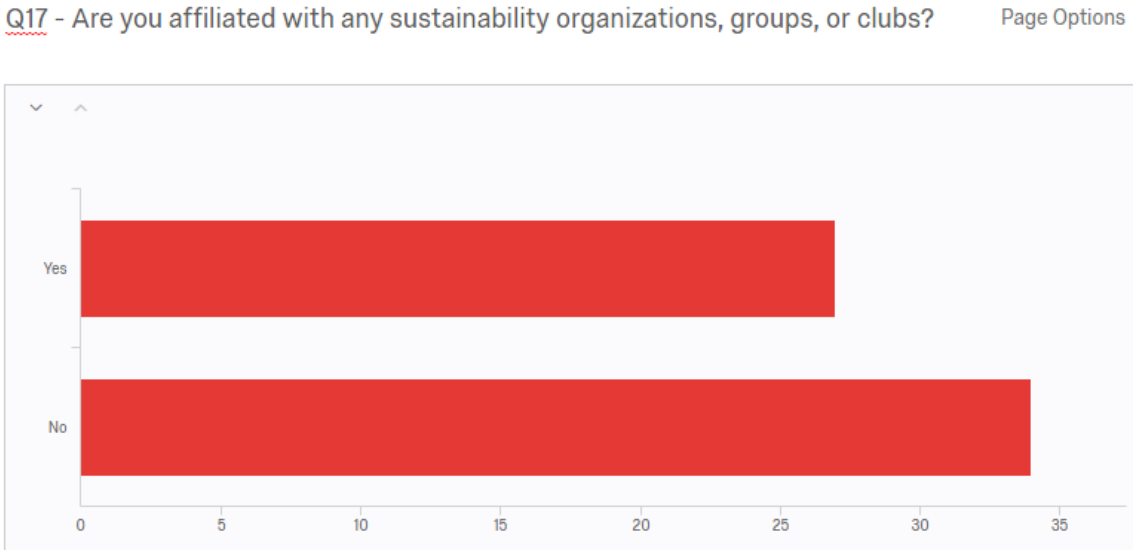

Figure 21: Q17 responses

The results for this question were surprising. 45% of responders said they were affiliated with sustainability related organization, and 55% responders said they were not. The suspicions for response bias from Question 16 are somewhat confirmed; almost half of the survey respondents are already invested to some degree in sustainability.

Moving forward to ask the users about their interests in the project. We try to mobilize the users get some ideas about the importance of the sustainability, from there they can become more sustainable in the future.

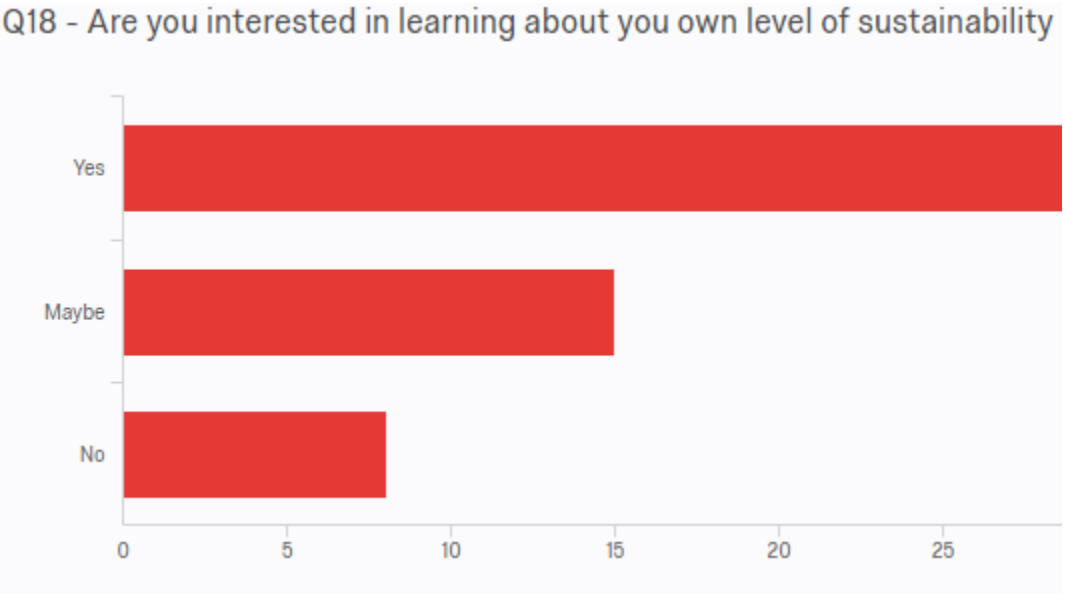

Figure 22: Q18 responses

It is pleasant to see more than 80% respondents say that they are willing to learn about the project. Clearly, there is some amount of interest in the service provided by our application.

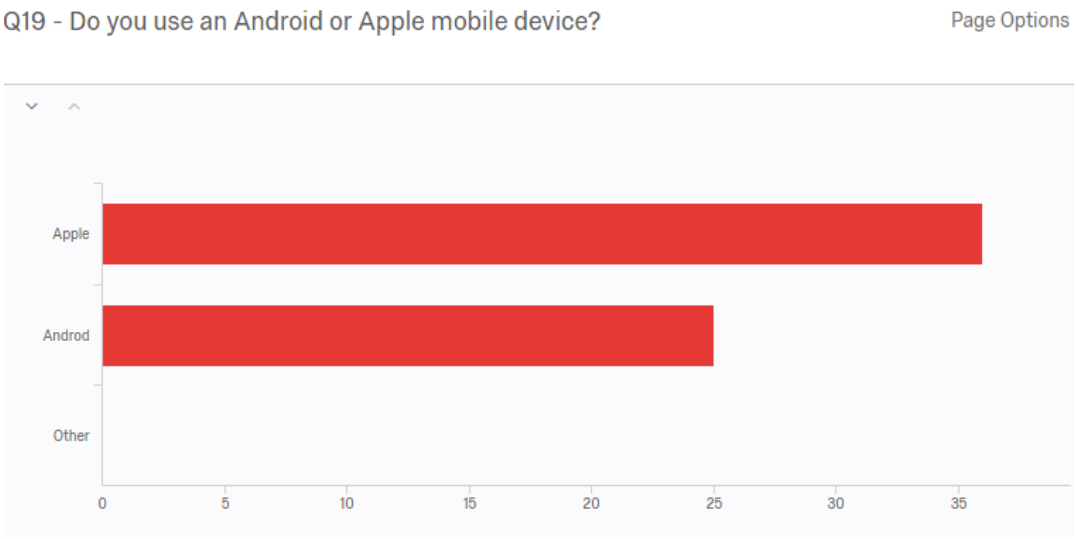

Figure 23: Q19 responses

All the 61 respondents said that they have either an Android or Apple mobile device. Although our application is developed for Android and is unusable by those with Apple products, it is interesting to note that there were no individuals with other mobile device OS, as well as how all respondents had a mobile device of some sort. It shows that if this application was ported to Apple platforms, there is an even larger user base that can be accessed.

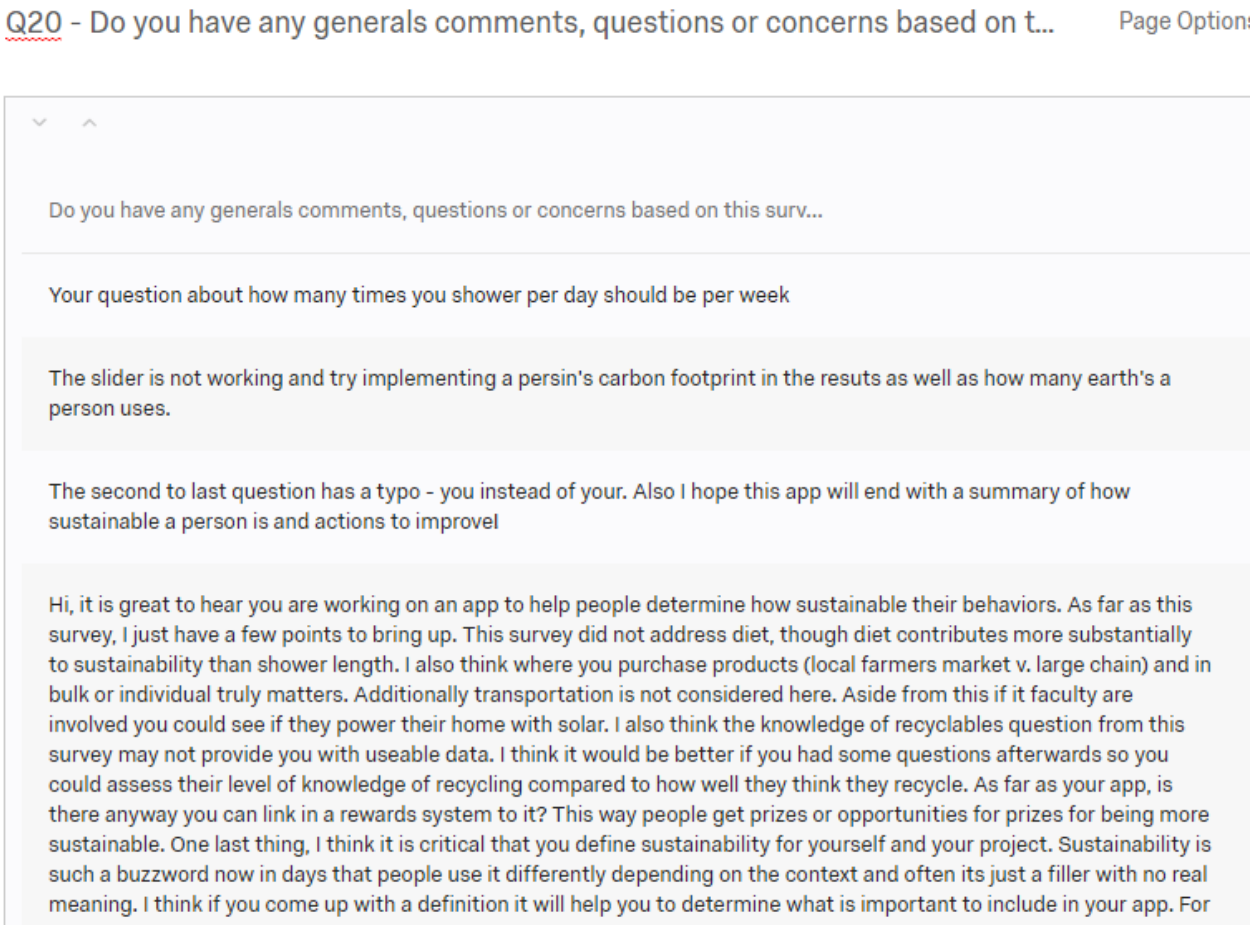

Figure 24: User feedback

The final comments offered by the users were useful in improving the overall quality of the survey. They helped catch small issues, such as grammatical errors, as well as larger conceptual ones, such as topics discussed in the survey.

6 Non-Technical Application Description

6.1 Introduction

The application was designed in Android Studio version 6.6.2. The code base is written entirely Java and XML. There is a repository that can be found on Github that can be found using the following link: https://github.com/1nkling/IQPSustain.

6.2 Initialization / Overview

The application starts up with a splash screen describing the current contributors as well as the supporting faculty and institutions. Then, users are directed to a homepage where they can see instructions on how to use the application, results of their past performance, and most importantly, take the survey. The application ships with an XML file that contains questions and their various parameters that will be parsed from by the application and used to generate the questions that are displayed to users. Once users complete the survey, their input is saved and they are offered a grade based on their responses in a following page that they can return to at any time. Additionally, they are offered recommendations on how to improve on their past performance.

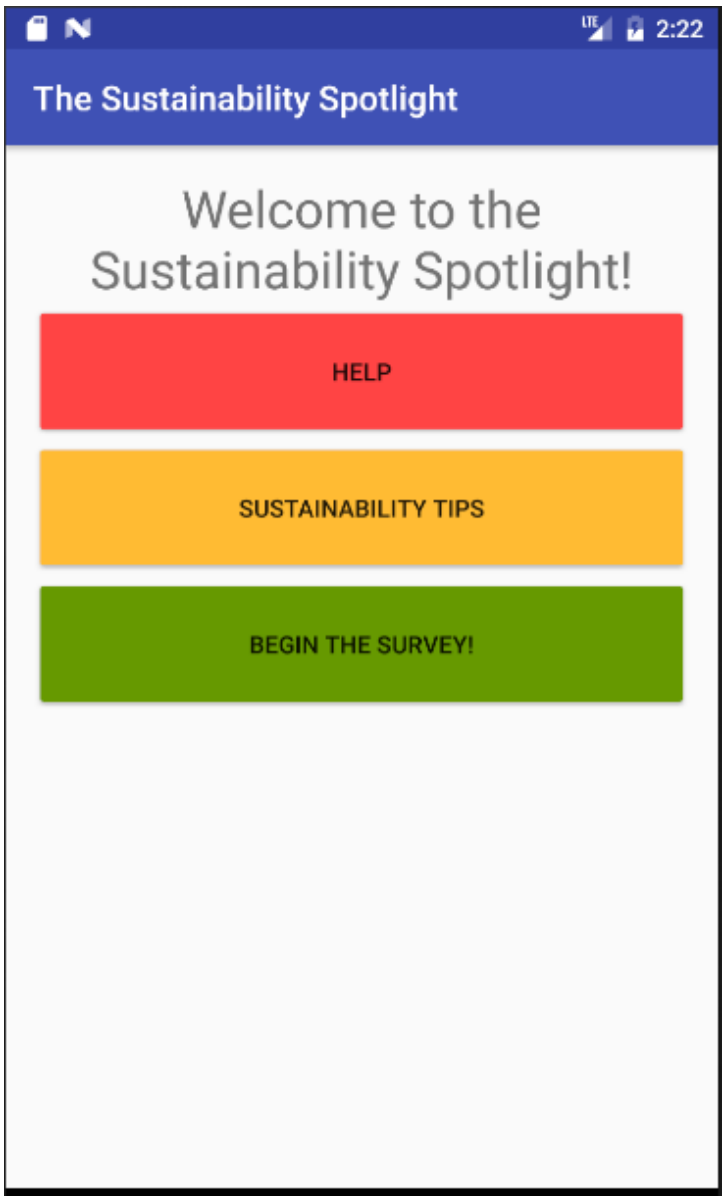

Figure 25: Homepage of application.

6.3 Survey

This survey is the same one that was administered using Qualtrics, but with the improvements obtained from user input in the Qualtrics trial survey. When users choose to begin the survey, they are presented with all the different dimensions that are present in the fields of questions in XML files in the form of buttons. If users select one of these buttons, they will be directed to a screen that contains all the questions in that dimension as well as fields in which the users can respond to these questions. When users fill in their responses to the questions in the fields available, they have the opportunity to submit them to be graded (send) or to return to a

previous screen and have whatever answers they have provided to be saved or not depending on which they would prefer.

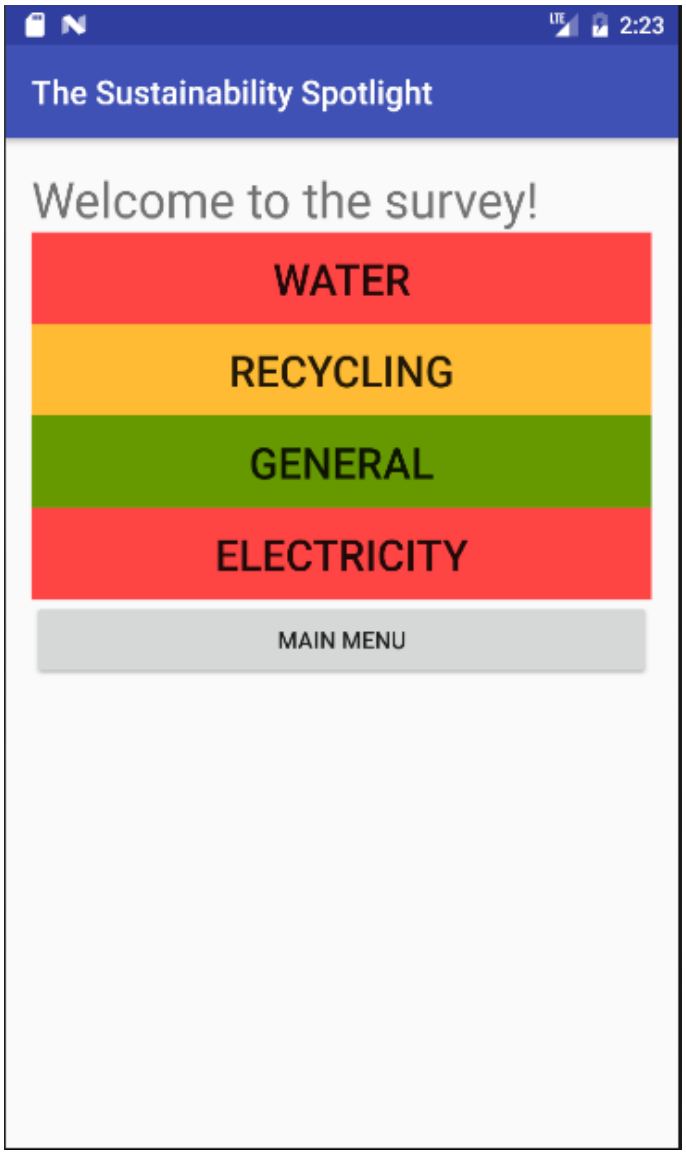

Figure 26: Dimension select screen for the survey.

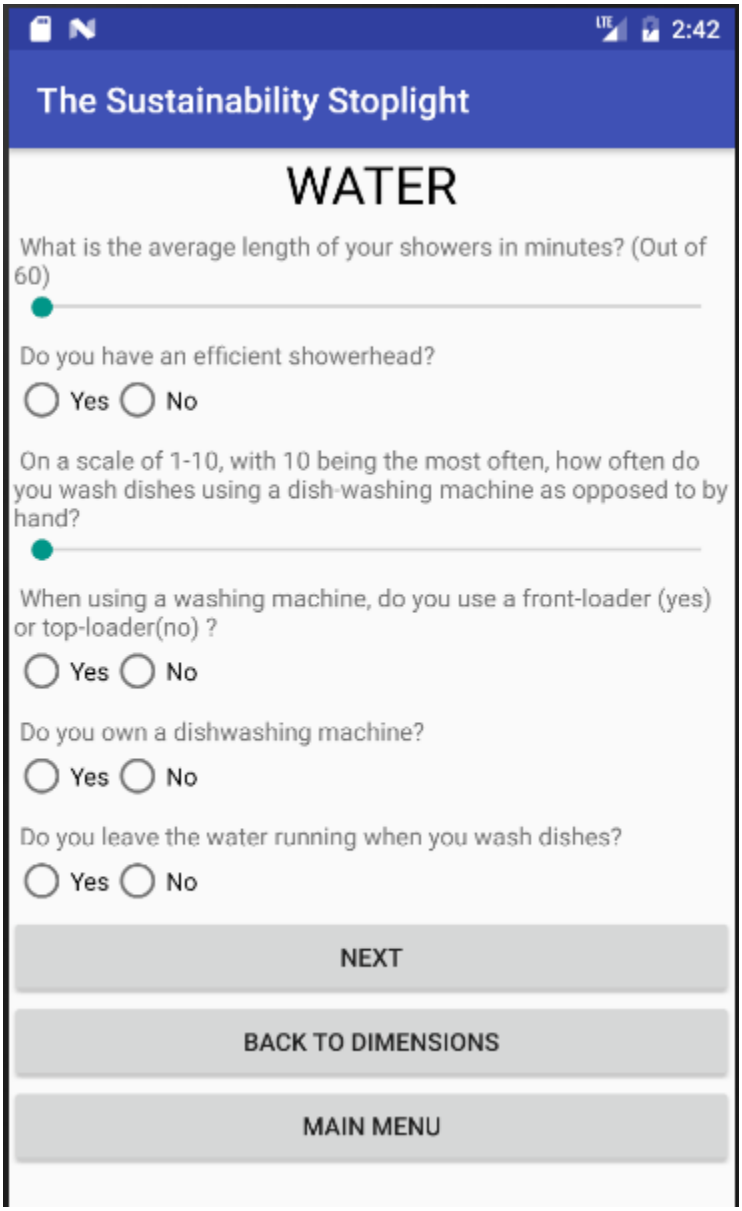

Figure 27: Sample input screen for a survey

6.4 Grading / Recommendations

After users completes the survey, they are directed to the main menu to check their performance with a button that if clicked, will send users to a screen containing a grade of the users' sustainability as a whole as well as for specific dimensions. Additionally, there will be recommendations offered to the users as to how to improve their current standing in areas where they performed poorly.

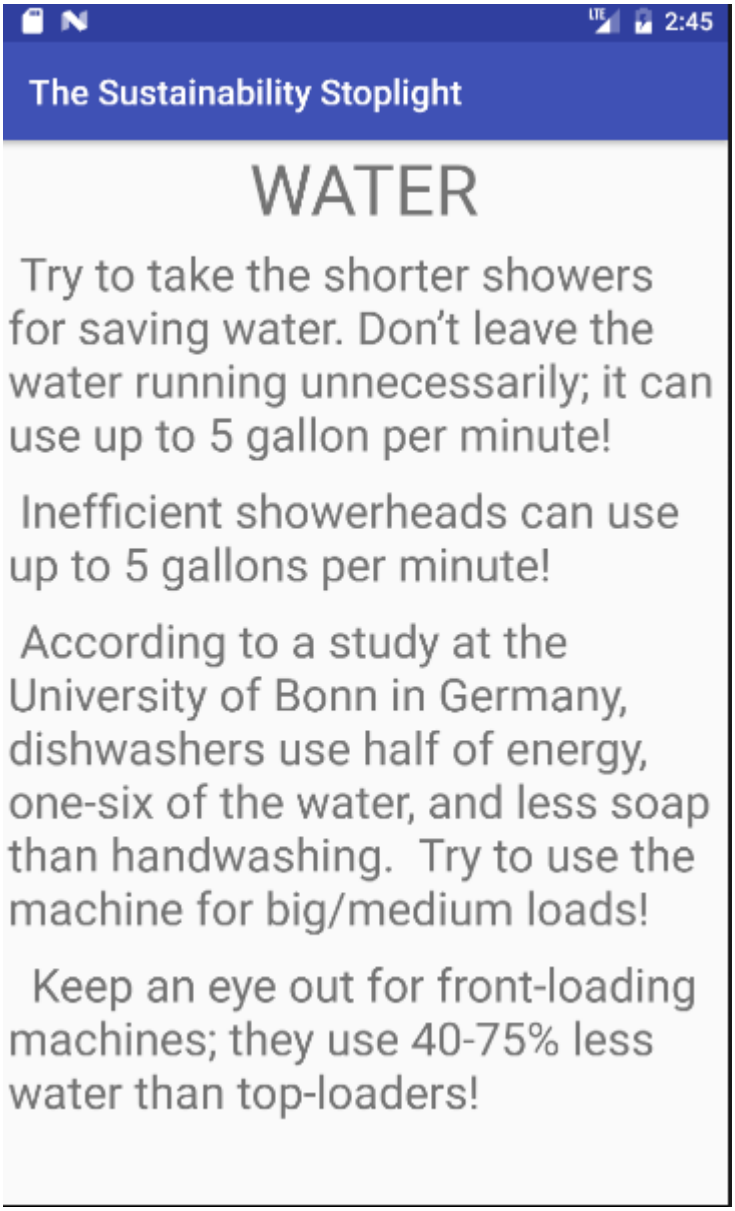

Figure 28: Sample recommendations

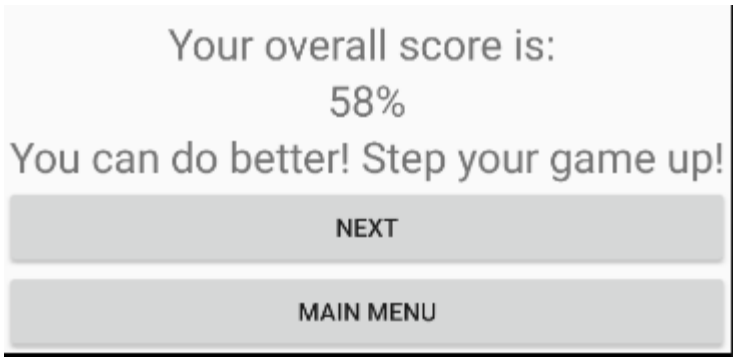

Figure 29: Sample grading for user performance

7 Technical Description

7.1 XML Parsing

The fields of the question objects are obtained using XmlPullParser. After initializing the factory, the XML file is parsed for specific tags that correspond to the fields in the question objects. The data within these tags are then parsed into a string or integer depending on their type and used to generate the objects.

```
<?xml version="1.0" encoding="utf-8"?>
<questions>
    <question>
        <q> Do you use a high efficiency showerhead? </q>
        <id>0</id>
        <respType>bool</respType>
        <maxScore>30</maxScore>
        <isLowGood>true</isLowGood>
        <dimension>water</dimension>
        <rec> Try to take the shorter showers for saving water. Don't leave the water running unnecessarily; it can use up to 5 gallon per minute!
        <famID>1</famID>
        <famType>1</famType>
        <myFamType>0</myFamType>
    </question>
    <question>
```

Figure 30: Sample question XML structure

7.2 Question / Answer Objects

The building blocks of the survey are question and answer objects whose fields are used to generate the necessary question and answer fields on the survey. Question objects contain the following fields:

- q: The question itself.
- id: An identifier for a specific question block.
- rec: The recommendation provided for users if they scored poorly on that question
- maxScore: The maximum score that the user input is compared against.
- isLowGood: Boolean value that determines whether a low score is good or a high score is good. For example, if the question is, "how much gasoline do you use monthly", a low value is good. However, if the question is, "how often do recycle", a high value is good.

- respType: Allows for adjustment the type of response field, such as a slider, radio buttons, or other forms of interactive responses.
- Dimension: The dimension that this question belongs to.

Answer objects relate one to one to a respective question object. They contain the following fields:

- EditText: The field where a user's response can be provided
- Text: The text to be placed in the EditText field when it is initialized; typically the previous response given by the users.
- id: An identifier for a specific Answer block.
- dim: The dimension that this Answer belongs to.

These two objects are combined in the QuestionAndResponse object, which contains the following fields:

- Question: A Question object.
- Resp: A Response object.
- id: An identifier for a specific QuestionAndResponse block.
- Content: The LinearLayout where the Question and Answer fields are initialized.
- Q: the TextView where the Question field is displayed.

7.3 Dimension Select

In the dimension select screen, the different dimensions are parsed from the XML file of questions. These are stored in an arrayList in a SurveyMap object. By using these dimensions, the different dimensions are dynamically generated as buttons as described in the init() function. The color of these buttons are cycled through three different colors described in the color() function. Whenever one of these buttons are selected, the intent is switched to the AbstractSurvey Activity. Additionally, a message containing the string of the selected dimension name is passed along with this intent. Similarly, the main menu button that is always present as described in the activity_survey.xml will switch the intent to the MainActivity Activity. In this case however, no intent is passed.

7.4 Question Generation

In the survey screen, there are several things that are instantiated before the questions are generated. Firstly, the name of the section, along with many other features, are derived from a message that was passed from the previous dimension select screen. This is represented as a TextView at the top of the screen. Next, there are the Next, Back, and Main Menu buttons that are generated at the bottom of the screen. When Next is selected, the intent is passed to the same AbstractSurvey Activity. However, it passes along another message that contains the string of the next Dimension to build the survey. When Back is selected, the saveAnswers() function is

called, which writes all current user input into an XML file that is used to evaluate user performance later. Afterwards, the intent is passed back to the SurveyActivity Activity. When Main Menu is selected, the same saveAnswers() function is called, but the intent is passed to the MainActivity Activity afterwards.

The way the questions are generated are described in the init() and populate() functions. In the init() function, a SurveyMap object that contains all the Question/Answer/QuestionAndAnswer objects that are needed to create the survey are instantiated. Once they are initialized, the init() function generates TextViews and the respective response Views for user input for each QuestionAndAnswer ArrayList.

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