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Reduction of the Consumption of Electricity in a Residential Neighborhood

An Interactive Qualifying Project Report

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Abstract:

The purpose of this report is to help consumers to save money with regard to their electrical bills. A number of energy saving possibilities is discussed, and through collection of data from the Power Company, direct survey, and usability studies, we examine some of the options in detail. These possibilities include: a redesign of the power bill, a guide to help consumers understand appliance usage, and a device to help consumers gauge their electrical consumption between power bills.

Executive Summary:

This project is a multi-faceted study of the consumption of electricity by Massachusetts Residences. It includes: (1) a direct sample of yearly electrical usage by Massachusetts Electric Customers in a specific neighborhood in Massachusetts; (2) a direct survey of the same population sampled by Massachusetts Electric to determine (a) appliance ownership information, (b) determine opinions on the Massachusetts Electric bill, and (c) determine their opinions and behavior with respect to energy conservation programs; a usability study of the Massachusetts Electric Company power bill. Based on the results obtained from these three studies, we have formulated several recommendations in hopes they will ease consumer frustration with their electric bills, save consumers money, and reduce overall energy consumption. (1) Our first recommendation is to develop a pamphlet to help consumers become better educated about their appliance usage. Because all electrical usage can be traced to the use of a specific appliance, we feel this is the first step in helping consumers save money and conserve electricity. (2) Our second recommendation is a redesign of the Massachusetts Electric Company Bill. Our usability study indicates that consumers had difficulty with specific parts of the bill, and alleviating those difficulties would go a long way to easing consumer frustrations. (3) Our final recommendation is the implementation of a device to better inform consumers of their energy consumption patterns. Some of our research indicates the implementation of such a device could help consumers save substantial amounts of money, and conserve a significant amount of electricity.

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Table Of Contents

Authorship Page

Key:	SC	=	Seth Chandler	JW	=	Justin Wheeler
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1 Cover Page,Abstract, Executive Summary, TOC, etc. .... SC

2 Background and Introduction .... SC

3 Statement of Objectives .... SC

4 Literature Review .... ***
  4.1 Conservation and Usage Information .... ***
    4.1.1-4.1.4 .... SC
    4.1.5 .... JW
  4.2 Survey Literature .... MC
  4.3 Usability Study Literature .... JS and SC

5 Methodology .... ***
  5.1, 5.4 .... SC
  5.2 Goal 1: Amount of wasted energy on average per household. .... ***
    5.2.1, 5.2.3 .... SC
    5.2.2 Direct Survey of Mass Electric Company Customers .... ***
      5.2.2.1, 5.2.2.2, 5.2.2.5, 5.2.2.7-5.2.2.10 .... SC
      5.2.2.3 Determine Specific Questions .... ***
        5.2.2.3.1, 5.2.2.3.3, 5.2.2.3.4 .... MC
        5.2.2.3.2 .... SC
      5.2.2.4, 5.2.2.6 .... MC
  5.3 Goal 2: Help consumers understand their power bill. .... ***
    5.3.1 .... SC
    5.3.2-5.3.9 .... JS

6 Results .... ***
  6.1 Introduction .... SC
  6.2 Goal 1: Survey and Mass Electric Data .... ***
    6.2.1, 6.2.3, 6.2.4 .... SC
    6.2.2 .... ***
      6.2.2.1 .... MC
      6.2.2.2 – 6.2.2.4 .... SC
  6.3 Goal 2—Usability Study Results .... JS and SC
  6.4 Device Design .... ***
    6.4.1-6.4.2 .... SC
    6.4.3 Cost .... JW and SC

7 Analysis .... ***

List of Figures and Tables

Tables:

Figures:

2 Background and Introduction

2.1 Reasons for Conservation

The conservation of natural resources has been the subject of scientific, economic, and social debate for some time on the international stage. Since the energy crisis in the United States in the 1970's, our country has been extremely concerned with conserving energy as well. Our project is based on the need for information regarding the waste of electricity in a residential neighborhood, and education of the residential consumer with the assistance of our newly garnered information. Enormous volumes of information on the benefits of conservation of energy exist, but much of the information on the waste of electricity is focused on industrial applications rather than residential areas.

Conserving electricity is a large part of our project, and conservation has a number of benefits for the consumer, the electric company, and the environment. On the consumer basis, conserving electricity saves money on their electric bills. On the environmental basis, less energy consumed means less damage to the environment, and for the power company less consumption creates greater availability, and reduces the strain on generating capacity.

2.1.1 Saving Money

For consumers, conserving electricity saves money on their electric bills. This accomplishes a number of different tasks all in one: economic stimulation, and further conservation, among other things. The money saved by conservation of electricity is injected directly into the economy in one way or another; a consumer has freed up part of his income for use in another area. This feeds the second of some of the benefits mentioned above; one of the areas the consumer may wish to invest in is increasing his home's energy efficiency. This in turn works to free up even more money, and the cycle continues.

2.1.2 Helping Environment

The second major impact conservation can have on society and the world in general is indirectly working to help protect the environment. The majority of the energy generated in the United States is not 'clean,' but rather generated through the burning of coal. While hydroelectric, solar, and wind power are viable options for power companies, the cost-effectiveness of these technologies is far inferior to that of coal burning generators. While nuclear power may be a clean alternative to coal, its use is very limited, and other concerns, such as safety, have prevented an increased adoption. The By increasing consumption, you reduce the amount of energy required, and thus the amount of fuel necessary to burn to generate that electricity.

2.1.3 Reducing Load on the Grid

When one house saves electricity, this also reduces the load of the grid. The instantaneous load on the grid affects the generation and transmission costs incurred by the electric company in providing residential customers with power. As these costs vary, the electric companies can petition to the state to change their tariff structures in order to cover any additional costs. In addition, high instantaneous grid-loads have been the main problem behind California's energy crisis. If the load were lower, the rolling blackouts started by Cal-ISO would probably not be necessary at all.

It would thus be wise for consumers to examine the benefits to themselves, the environment, and their communities when deciding whether or not to conserve electricity. Clearly conservation alleviates or helps to alleviate a number of problems that have been plaguing our country for some time; this in and of itself should be significant enough to warrant the widespread adoption of some well-established methods of conservation, and the creation of newer and more effective methods of conservation as well.

2.2 Why we decided on this particular project

There are several reasons why we decided to do this project, including: helping consumers save money, learning more about conservation of electricity, and learning more about the way the power company works. Helping consumers save money was a large part of the reason for us to do this project. We know that electric bills can be a substantial expense for consumers, and helping them save money anywhere they can is usually welcome assistance. The second reason we chose this project is because we are concerned about the environment and felt that one of the best ways to try and alleviate some environmental problems is to encourage consumer conservation. The final reason we chose this project is to gain a general understanding of the way the power company works. We will be paying our own electric bills soon enough, and learning how the bill works will be useful knowledge.

3 Objectives of the Project

The small subset of the benefits of energy conservation established above should be reason enough to encourage consumer energy conservation. If many consumers try to save money on their power bills, then other benefits may indeed manifest themselves, such as reduction of emissions by coal-burning generating facilities. This project has been created in order to help consumers better understand how they use their electricity, and thereby motivate them to conserve its use. Residential consumers waste millions of kilowatt-hours of electricity each year; if conserved, this energy could help the consumer save a substantial amount of money each year. We have divided our project into what we feel are three sufficiently different objectives, all of which are intertwined at some point or another.

3.1 Determine how much electricity people waste on average

First of all, one of the most important objectives of this project is determining how much energy is wasted by consumers. Our ultimate goal is to determine not only how much energy is wasted, but also what the major causes of energy waste are. This information will help us determine possible solutions and recommendations for reduction of energy waste.

3.2 Means to help average consumers understand their power bills

Next, most homeowners do not know how to read their monthly electric bills; this is a major lapse in consumer education, because they have no idea how they are using their energy. The power bill must be more user-friendly to the consumer, whether through a redesign of the bill, or a guide to the current bill. Although this will play a part in helping the consumer save money and understand his electricity consumption, it is an important distinct objective on its own.

3.3 Help consumers to conserve electricity and save money on their bills

Consumers should also be aware of how much energy they waste each year; armed with this knowledge, they will be better able to help themselves. Accomplishing the first objective will give us the opportunity to help the consumer become conscious of the amount of energy he wastes, where and how he wastes it, and eventually how he can conserve electricity. Thus, saving the consumer money and helping him conserve electricity becomes an objective in and of itself.

4 Literature Review

Because of the diverse number of topics covered by this project, a comprehensive literature review is required to insure a sound experimental design. Many of the ideas we planned to use in our project have been tested before or commented on in previous literature. This information will be located and reviewed in detail not only to insure sound experimental design, but also to give us a broad base of topics to choose among and focus on.

4.1 Conservation and Usage Information

4.1.1 Determining Energy Consumption

4.1.1.1 Introduction

In order to attempt to gauge conservation of electricity in a residential area, it is first necessary to understand where the energy is used, and what precisely it is used for. Determining these two primary factors allow a much better understanding of the consumer both on average and as an individual. The consumption of electricity in a household can generally be defined as the sum of the consumption of the individual appliances in the house (Parti and Parti, 1980). This is obviously true, but the factors which influence individual appliance usage, and thus the total consumption, are quite complicated. A number of methods have been devised for determining electrical usage in the home, including: experimental studies, theoretical calculations, direct surveys in concert with other collected data, and the use of data disaggregated down to the appliance level.

4.1.1.2 Experimental Studies

A number of experimental studies have been conducted on demand for residential electricity, most of those appearing after the energy crisis in the mid 1970's. The majority of this work however, dealt with the acceptance of new methods for encouraging conservation of electricity. The generally accepted measure of consumption in electrical usage in all of these studies was meter-reading, whether that was on a weekly or monthly basis (Battalio, Kagel, Winkler, and Winett, 1979). If the only information required is the consumption of electricity per household, this is an adequate measure; however, if more detailed results are necessary, more elaborate methods must be used.

4.1.1.3 Theoretical Calculations

Another accepted estimation of electrical consumption is theoretical calculations. Theoretical calculations based on engineering data are predominantly used in end-use forecasting to estimate the amount of electricity required to serve a specific area. The engineering data spoken of is average appliance-specific information, in order to estimate the use on a household-by-household basis (Parti and Parti, 1980). There are several difficulties with this method of estimation however; some studies (e.g., Parti and Parti, 1980) have found that engineering estimates for appliances can be significantly different than actual empirical observations. The reasoning behind this effort is obvious: as previously mentioned, the amount of electricity a household consumes is the sum of the amount of energy consumed through appliance usage. The importance of data disaggregated to the appliance level cannot be overstated; knowledge of what appliances are used and when not only allows the estimation of power consumption, but the development of appliance-specific conservation programs as well. While this particular method for determining electrical consumption is inexpensive, the inadequacies of the engineering estimates may taint the data, thus invalidating the work.

4.1.1.4 Surveys in Concert with Measured Data

A number of solutions to the problem of inadequate engineering estimations exist. One solution is the direct metering of every significant appliance in the house over time, to develop average usage numbers. This method for determining appliance usage is not only extremely time-consuming, but the cost is outrageous. A better solution to this problem is combining existing metering data with collected information through direct surveys. Parti and Parti did just this in their disaggregation of electrical usage to an appliance-by-appliance level. The primary benefits of determining usage information in this manner are the relative inexpensiveness of the survey when compared to direct metering and the accuracy of the data over engineering estimates.

The basic experimental design used by Parti and Parti involves a number of different and seemingly unrelated pieces of information. In order to obtain a more accurate measure of monthly appliance-specific information without actually metering every appliance, they decided simply to correlate monthly electrical data from "5000 individual households," and "merge[d] with weather data and an unusually detailed set of appliance ownership and demographic variables for the corresponding households."

Then armed with this data, they did a number of regression analyses to separate the data into categories not only for demographics, but also into categories of appliances. This approach to the problem allowed Parti and Parti not only to reach accurate estimates, but also to do it in a relatively inexpensive fashion.

4.1.1.5 Appliance-Specific Information

As previously mentioned, information exists through both engineering estimates and experimental studies on specific appliances. In several studies, such as the Parti and Parti study, or the Dubin, Miedema and Chandran (1986) study, appliances are disaggregated in- to several different categories. Dubin, Miedema and Chandran listed several main appliances as important to electrical consumption: electrical refrigerators, ovens, ranges, microwave ovens, and freezers, washers, and clothes dryers. The study was focused on electric heating and cooling devices, which are generally considered to be the devices with the largest energy consumption.

4.1.1.5.1 Heating and Cooling

Generally cited as consuming the largest amount of electricity of all of the appliances used in the home, residential heating and cooling units obviously account for the largest portion of the electric bill. Electric heating devices account for quite a bit of electricity, because not only do they generate heat with electricity, the fans are required to move the heated air throughout the house. This is the same reason why gas and oil heat, although using different fuels to generate the heat still draw electricity: to circulate the air through the residence. Air conditioning is similar to electric heat, in that not only is the cooling done with electricity; it requires electric fans to circulate air. In Dubin, Miedema, and Chandran (1986), it was found that heating and cooling did indeed account for a large part of the electric bill. This held similar to findings by Parti and Parti, 1980, that large amounts of electricity were used by electric heating and air conditioning units.

4.1.1.5.2 Other Appliances

While heating and air conditioning account for large amounts of electrical consumption, other appliances still require quite a bit of electricity. The appliances that Dubin, Miedema and Chandran mention in their study as other significant factors are for the most part included in the Parti and Parti study. Appliances that Parti and Parti mention as significant in addition to heating and cooling are electric water heating, dishwashers without the benefit of an electric water heater, electric ranges, electric dryers, freezers, televisions, refrigerators, and a group of other unspecified appliances. The televisions and refrigerators are further disaggregated into black and white and color televisions, and frost-free and non-frost-free refrigerators. The appliances with the largest draw other than the heating and cooling units are water heaters, frost-free refrigerators and freezers. The Parti and Parti study does leave out washing machines and microwave ovens as major contributors to electrical consumption, although they may be included in the category 'unspecified appliances'.

4.1.2 Factors Affecting Conservation

4.1.2.1 Introduction

Much like the number of different factors that weigh on the demand for electricity, the need for conservation and amount of conservation actually observed depend very much on the situation. The past two summers in California are a perfect example of this; conservation has gone from an attitude to a necessity (California ISO Press Release, 2001). While the need for conservation is ever-increasing, the number of its proponents and the amount of support they provide depend a great deal on factors such as the current price of electricity, the support of electrical companies, and the demographics of the target population.

4.1.2.2 Price

The first major factor in the amount of support for conservation is price. This would seem to be intuitively obvious, but it is important to be noted. A number of attempts to encourage conservation revolve around the reduction or variation in price for efforts to conserve, or the use of electricity at different time intervals during the day or the year. In addition to this, the willingness of a consumer to participate in efforts to conserve is directly proportional to the cost of the electricity. A number of studies regarding this relationship exist, but most plainly stated, it is theorized that a 40% increase in the average price of electricity would translate into a 20% decrease of electrical consumption (Parti and Parti, 1980). While the increase in price is staggering, the 20% decline in usage is significant; this may indeed turn out to be the solution to supply problems in the future, but as yet methods resorting to penalty systems and outrageous prices have not been implemented.

Similar evidence supporting the theory that price has an inverse relationship with the amount of energy used was found by Hirst and Carney (1978), and Hirst and Hannon (1979). The former conducted a theoretical study of the amount of money spent on energy, and the amount of energy used in our country based on a number of different scenarios. The scenarios which reflected the most dramatic price increases showed the highest reduction in energy consumption. They did not however suggest implementing price inflation to reduce consumption; merely that the model they used indicated that increased price of all energy sources lowered energy use. The latter conducted similar studies but with respect to both residential and commercial areas; using a similar experimental design, they obtained the same results. Programs that included price increases demonstrated a decrease in the amount of energy consumed.

4.1.2.3 Advertising

One may look at the title of this section and balk, but advertising plays a major role in the success or failure of conservation efforts. Kaserman and Mayo (1985) examine the effect of advertising by energy companies on the observed conservation by the consumers and found interesting results. First, it is important to emphasize that their study was done to examine the options for electric companies with regard to advertising for conservation in order to exploit the period between adjustments in tariffs. This may sound underhanded, but our examination is not of the motives of electric companies to suggest conservation, but the effect of the advertising resulting from those motives. The results of the investigation are both heartening and disheartening at the same time.

The correlation study found that advertising had a negative effect on usage. This would indicate that the majority of the advertising done was to promote conservation, and that the advertising was at least marginally effective. This correlation indicated significance on the 5% level, which clearly gives merit to the claim that advertising affects consumption. The difficulty with the findings is not in the significance of the results, but in the amount that advertising affects electricity. While the results are significant, the elasticity of the advertising is extremely low. In fact, according to their study a "10% increase in conservation advertising expenditures results in less than a two-tenths of 1% decrease in electrical consumption." Thus, while advertising does have an effect on conservation, it is difficult to encourage conservation by broadly advocating conservation through advertisements.

4.1.2.4 Demographic

Just as price and advertising play a role in the conservation of electricity, demographics play an important part as well. The most significant demographic figure to be examined in the case of conservation is income. It is commonly thought that income does play a major role in efforts to conserve electricity, but the actual correlation between conservation and income runs contrary to popular belief. The easiest way to measure the effect and elasticity of income on efforts to conserve electricity is to vary the price; this is a method that a number of experimental and observational studies have used, and the results are clear. When adjusting the price of electricity, the general effort to conserve, that is an observed reduction in consumption, is proportional to the income of the participants. Plainly, when price is the determining factor, the higher the income, the larger the effort is to conserve (Parti and Parti, 1980).

4.1.3 Established Methods of Conservation and Their Results

4.1.3.1 Introduction

Stemming originally from the need for conservation during the energy conscious times of the 1970's, and more recently during the aforementioned energy crisis in California, the need for conservation has led to the establishment of a number of different programs aimed at helping the household consumer save electricity (House Committee on Resources Oversight Hearing: National Energy Policy, 2001). Though the success and failure of these programs eventually depend on the acceptance by the consumer, the ideas motivating the design of the programs are important to understand. Whether the programs are extant today has a fair, but not exact correlation with the amount of energy they are able to save. Generally speaking, a program should be accepted if its cost ends up being less than the amount that it saves (Joskow and Marron, 1993), but the estimations involved for both cost and conservation are often grossly underestimated and overestimated respectively. An examination of past programs, their successes and failures, and an analysis of their results will follow.

4.1.3.2 General Effects of Conservation Efforts

Information on the effects of conservation efforts exists in both theoretical calculations and actual observations. The theoretical calculations take into account both economic and social factors to determine the effectiveness of the efforts. An effort may be successful in reducing the consumption of electricity, but if the costs greatly outweigh the benefits of the lessened consumption, the method will rarely be adopted, except in extreme cases.

4.1.3.2.1 Theoretical Calculations

Much of the work in theoretical calculations on economic and social effects of differing energy plans is covered by Hirst and Carney (1978), and Hirst and Hannon (1979). Both studies used the Oak Ridge National Laboratory's forecasting equation to predict the use of all types of energy, not just electricity, in the future. One of their most important results is the prediction that electrical consumption will increase at a rapid rate, while the increases in oil and coal consumption will drop off (in percentage of energy produced). Through both theoretical studies, several different effects were observed for different efforts to curb energy consumption.

4.1.3.2.1.1 Effects on Consumption

The major effect observed by both Hirst and Carney and Hirst and Hannon is the effectiveness of certain programs in reducing energy consumption. Different programs have different effects, but it is clear through their experimental designs that the price of energy and construction of buildings and appliances play a large part in how much energy is consumed. The more stringent the standards employed for building construction, and the design of new appliances, the more energy is saved. The higher the price of energy, the more energy is conserved by the residential customer. The question then is which scenarios are effective based on the economic effects of the different plans.

4.1.3.2.1.2 Effects on the Economy

The economic effects of the conservation programs evaluated by Hirst and Carney become apparent when examining the cost and benefit numbers included in their report. When reasonable conservation methods are employed, an initial cost must be endured. After the initial expense is weathered, the conservation techniques tend to pay for themselves in a short amount of time. After the savings in electricity have covered the start-up costs, the savings go directly to the consumer, allowing for an increase in available income on average.

4.1.3.2.2 Actual Calculations

While theoretical calculations can back up a project initially, the observed effects of those programs will ultimately determine their continued existence. Though theoretical calculations indicate the benefits of some conservation programs to be tremendous (Hirst and Carney, 1978) (Hirst and Hannon, 1978), they are not always necessarily correct.

4.1.3.2.2.1 Effects on Consumption

An analysis of heating and cooling installations in Florida by Florida Power and Light by Dubin, Miedema, and Chandran runs contrary to many theoretical calculations.

The root of the problem is that more efficient heating and cooling devices "lower the effective price of the services they provide (or are associated with) and, consequently, reduce electricity consumption by smaller amounts than anticipated in engineering estimates" (Dubin, Miedema, and Chandran, 1986). In other words, because efficient appliances cost less to run, people are more willing to use them. This negates the possible effect that efficient appliances have on consumption. Therefore, although some programs may in theory reduce the amount of electricity consumed, it is possible that by reducing the cost, they increase use, and have no net effect on consumption.

4.1.3.2.2.2 Effects on the Economy

If some programs end up having no net effect on electrical consumption, then the effect on the economy is extremely different from the effect predicted by theoretical models. While customers may purchase new appliances such as air conditioners with the intention of saving money through their new-found efficiency, they may indeed end up using their new product more than anticipated; this is clearly a double-edged sword. By using the device more than anticipated, and using the same amount of electricity, the appliance no longer pays for itself as theoretical models suggest. The extra cost of the appliance is then absorbed wholly by consumers, without any benefits save a relatively higher standard of living.

4.1.3.3 Rebates and Bonus Payments

The use of rebates and bonus payment programs to increase conservation in the residential sector is commonly thought of as an effective method. A number of experimental and theoretical studies examine the effects of price variance on efforts to conserve. We have already established the fact that the higher the price of energy, the more people try to conserve. Up till now however, we have given little consideration to the use of a decreased price as an incentive to conserve. The ideas behind both concepts are similar: consumers, generally speaking of course, like to save money. A consumer might be willing to go through the extra trouble of conserving electricity if he were to see a noticeable benefit.

One of the objectives of a study by Battalio, Kagel, Winkler, and Winett (1970) was to determine the effect of rebates and incentives on the energy consumption of a feedback population. In order to simplify the analysis of their results, and to reduce the cost of the study, it was performed over one "Air Conditioner Season" in College Station, TX. There were five separate populations: one was given no material regarding conservation (thus they were the control group); a second was given government-prepared material related to conservation; a third group was given all of the information provided to the two experimental groups, but without the incentives; and finally two groups were given the government prepared material with regard to conservation and the ability to save money on their electric bill through rebates and incentives based on their conservation. The final two groups, subjects who were eligible for rebates, were divided up into a low price rebate group, and a high price rebate group, to estimate the elasticity of the rebates and bonuses on efforts to conserve.

Information was collected for two weeks prior to the sorting of the houses into groups, then a four-week treatment period followed. The houses received weekly feedback on their electrical consumption (data obtained from their electrical meters) and also received rebates and bonuses based on their use. Then, based on the preliminary experimental results, a second six-week treatment period was employed where a cross-over study was implemented. The information group, which received conservation literature, was put on a modified high price rebate plan, in order to determine the actual effectiveness of the rebate system. The two rebate groups had rebates for four weeks, and in the last two weeks of the treatment the rebates were removed. The initial numbers indicated the rebate incentive plan was effective with the two groups it was tried on, and this was further shown by the fact that when the rebates were dropped, the high price rebate group saved less energy. The incentive plan's success was also indicated by the fact that the information group, which was modified to include rebates, then showed significant decreases in electrical consumption. This is further evidence of the price elasticity discussed earlier; in general, manipulating price will cause conservation when using either significant rebates, or significant price increases.

4.1.3.4 Home Improvements/Code Improvements

One of the most significant ways in which the amount of energy used by our country is affected is through building codes and renovations. Improvements in the efficiency of building materials and designs, such as insulation, siding, and windows, can add up in the long run. There are generally two cases under which homes can be evaluated for energy efficiency: the house may not yet be built, or the house is to be retrofitted. Both of these options were examined in detail by Hirst and Carney (1978).

The Hirst and Carney (1978) study was a theoretical examination of the effectiveness of several different options (nine specifically) in the conservation of electricity. The study was based on the Oak Ridge National Laboratory energy-use model to predict prices and consumption of electricity based on a number of variables, such as fuel prices, income per capita, and population projections. The nine test cases developed included several proposed conservation techniques, and a number of extreme techniques as well. The first case kept the price of fuel static, allowing its use to grow unchecked. The second case, which they refer to as a baseline case, let the price of energy grow according to current predictions; this yielded some slowing in energy consumption. The third case established appliance efficiency targets, and found that the more efficient appliances end up paying for themselves over time due to the decrease in electrical consumption. The fourth case assumed that building standards were exacted to save energy, and they found in most cases these would pay themselves off in less than five years. The fifth test case involved the retrofitting of buildings, to meet standards of efficiency, and also paid off in several years. The sixth test case involved the implementation of all of the practices in cases three through five, and showed similar marked reduction in consumption, and costs that were outweighed by savings.

The federal government sets minimum standards for building construction with respect to energy efficiency. As mentioned above, one of the test cases in the Hirst and Carney study examined this very possibility. Under their test case, any new building constructed had to meet these federal standards. In test case five, they examined the other option, retrofitting of an existing house. These programs can be taken charge of by a number of different parties: the utility companies, the owner of the house, or the federal government.

4.1.3.4.1 Utility Subsidized Programs

One of the conservation techniques explored in detail by a number of different studies is utility-subsidized energy-saving projects. With these particular programs, utility companies would actually pay for consumers to have their homes audited and modified. Hirst and Carney's study found that while this method was effective, there was not always widespread use because either the customer was unaware of it, or uninterested in it, or the electric companies felt that the costs well-outweighed the benefits.

4.1.3.4.1 Government Programs

The government establishes certain standards for appliances, building materials and building construction in order to regulate the energy efficiencies of new buildings. At the time Hirst and Carney did their study, a number of government standards proposed by the Carter administration were passed into law. Most of these standards could be considered mandated standards, while others, such as voluntary retrofitting of a home, were incentive-based programs. The study also examined the effectiveness of more stringent standards than those passed into law, should the government decide to implement them, on either an incentive or mandatory basis.

4.1.3.4.2.1 Government-Mandated Programs

Government-mandated programs can be implemented in several different forms: building codes, and appliance standards. The government is responsible for setting building codes for work on existing buildings and new buildings, as well as standards for new appliances. However, the government currently does not require renovation of old buildings to include new energy-efficient technology (Hirst and Carney, 1978). Hirst and Carney examined the effectiveness of government-mandated programs, and determined that the effectiveness depended on the extremity of the particular program. In general, improved building codes and appliance standards provided a huge savings of electricity, and a very high benefit-cost ratio.

4.1.3.4.2.2 Government Incentive-Based Programs

Another of the government programs examined by Hirst and Carney was a government incentive-based program to retrofit housing with energy efficient materials in order to reduce electrical consumption. Though the two mandatory programs discussed above were theoretically effective, the most effective program according their projections was retrofitting old structures with newer materials. The total savings of 25 quads (1 quad = 1 * 10^15 British Thermal Units) was more than double the savings of the mandated programs, and the benefit cost ratio of 1.9 indicates these measures are not only effective in conserving electricity, but also effective in saving the consumer money.

4.1.3.4.3 Voluntary Programs

'Voluntary programs' is a misnomer of sorts; to a certain extent, it implies that consumers will take matters into their own hands as far as how energy efficient they want their homes to be. Aside from reimbursement through incentive-based programs, there is little to encourage consumers to modify their behavior, and they themselves must provide the motivation and weather the initial cost of the investment. Hirst and Carney found that although voluntary retrofitting of a house often had a greater effect on energy consumption, very few people would go to such measures without assistance from either the government or the power company.

4.1.3.5 Voluntary Rate Schedules

A relatively new and interesting development in attempts to conserve electricity, but also remove load from the power grid during peak hours, are voluntary rate schedules. The consumer is allowed to voluntarily choose whether or not to participate; different times of day correspond to different rates. The off-peak hours cost typically less than normal, and peak hours cost the same or more for the specific customer. There are several different ways to set tariffs for the prices; some can be set seasonally by time of day, others can just be set to peak and off-peak hours (Wenders and Taylor, 1976).

The effectiveness of these programs is the subject of much controversy however; because the programs are voluntary and experimental, it is difficult to say what would happen if the power system were restructured to manifest these price schemes. Some experiments show that customers will respond to these pricing schemes (Wenders and Taylor, 1976), while other studies argue their effectiveness is limited (Train, McFadden, and Goett, 1987). An interesting point to make, however, is that the effectiveness of these programs depends on how they are marketed. In research done by Train, McFadden and Goett, the programs would be made more successful by advertising them to consumers as a way to help themselves, rather than to help the power company or the environment. Other difficulties uncovered by their study were that for some uses, like residential cooling, rate schedules are effective. In other areas, such as residential heating, rate schedules fail to live up to their intended use. Though voluntary rate schedules are an interesting concept, getting consumers to voluntarily accept different rates based on time of use are difficult in practice, and sometimes less effective than estimates show.

4.1.3.6 New Appliances

One of the most significant developments impacting the area of electrical conservation is the constant development of more energy-efficient appliances. The impact that newer and more energy efficient appliances have on the usage of electricity was one of the very topics examined by Hirst and Carney. They found that the increasing efficiency standards for new appliances were one of the most effective methods for conservation. While the initial cost of outfitting a home with new appliances is a substantial expense, the Hirst and Carney study shows that in the long run those investments tend to pay off.

4.1.4 Consumer Attitudes

4.1.4.1 Introduction

While there are a number of options available to help increase conservation of electricity, and energy in general, to the consumer, much of the success of these programs depends on their acceptance by the consumer. Seasonal-time-of-day tariffs could be established by electric companies, but they would have to be implemented in a voluntary fashion. The same is true for renovating homes, or when buying new appliances: participation in programs is for the most part voluntary. The trick with getting any consumer to change from an established method to a new method is to give him a valid reason. Whether this is done with monetary reimbursement, or environmental arguments, consumer attitudes have to be altered in order to convince them to use new and different methods to save electricity.

4.1.4.2 Response to Established Methods

One way to determine the attitude consumers have on electrical conservation is to gauge the success and support of proposed or established methods. While some methods appear extremely successful in theory, it is possible that they might not be so quickly accepted. Wenders and Taylor are quick to point out that while seasonal-time-of-day pricing could save consumers money, few adopt it, either out of fear of it costing them more money, or because of its complicated nature. Train, McFadden, and Goett also point out that with time-of-day pricing schemes, often-times theoretical predictions as to who will benefit and for what reasons can be way off. Clearly there are different ways to gauge the success and failure of established methods: commercial success is just one facet of a new concepts development; other factors are involved, and to truly determine consumer attitudes, direct surveys of customers are the best way.

4.1.5 Appliance Specific Information

4.1.5.1 Introduction

In order to accomplish several of the objectives in this project, a detailed look at the energy consumption by home appliances is necessary. In addition, we must also examine some energy savings options for these appliances, which we may decide to relay to the consumer in the form of a pamphlet.

4.1.5.2 Calculating kWh consumption

In an effort to determine how much energy people waste on average, one must figure out how much energy people should be using based on the appliances they own. The residential sector uses almost one-third of the electric energy consumed annually in the United States (EPRI, 1986). "Electric appliances account for more than 80% of this residential energy use" (EPRI, 1986). Therefore, by not factoring in the different appliance loads for each household before averaging them, the end result will have a large margin of error.

To get a general estimate of how much electricity home appliances consume use the following formula to estimate the amount of energy a specific appliance consumes:

$$\frac{Wattage * Hours\ Used / Day}{1000} = Daily\ kWh\ consumption$$

Multiply this by the number of days you use the appliance during the year for the annual consumption. You can then calculate the annual cost to run an appliance by multiplying the kWh per year by your local utility's rate per kWh consumed (EREC, 2001).

For examples:

Window fan:

$$\frac{200\ watts * 4\ hours / day * 120\ days / year}{1000} = 96\ kWh * \$.085 / kWh = \$8.16 / year$$

Personal Computer and Monitor:

$$\frac{(120+150)Watts * 4\ hours/day * 365\ days/year}{1000} = 394\ kWh * 8.5/kWh = \$33.51/year$$

(EREC, 2001)

4.1.5.3 Energy Use of Some Typical Home Appliances

You can find the wattage of most appliances stamped on the bottom or back of the appliance, or on its "nameplate" (EREC, 2001). The wattage listed is the maximum power drawn by the appliance. Refer to the list below, which provides the energy consumption (Wattage) of some typical home appliances for some examples of the range of nameplate wattages for various household appliances:

Aquarium = 50-1210 Watts
Clock radio = 10
Coffee maker = 900-1200
Clothes washer = 350-500
Clothes dryer = 1800-5000
Dishwasher = 1200-2400 (using the drying feature greatly increases energy consumption)
Dehumidifier = 785
Electric blanket- *Single/Double* = 60 / 100
Fans
- Ceiling = 65-175
- Window = 55-250
- Furnace = 750
- Whole house = 240-750

Hair dryer = 1200-1875
Heater *(portable)* = 750-1500
Clothes Iron = 1000-1800
Microwave oven = 750-1100
Personal Computer
- CPU - awake / asleep = 120 / 30 or less
- Monitor - awake / asleep = 150 / 30 or less
- Laptop = 50

Radio *(stereo)* = 400
Refrigerator *(frost-free, 16 cubic feet)* = 725
Televisions (color)

19" = 110
27" = 113
36" = 133
53"-61" Projection = 170
Flat Screen = 120

Toaster = 800-1400
Toaster Oven = 1225
VCR/DVD = 17-21 /20-25
Vacuum cleaner = 1000-1440
Water heater *(40 gallon)* = 4500-5500
Water pump *(deep well)* = 250-1100
Water bed *(w/ heater, no cover)* = 120-380
(EREC, 2001)

If the wattage is not listed on the appliance, you can still estimate it by finding the current draw (in amperes) and multiplying that by the voltage used by the appliance. Most appliances in the United States use approximately 120 volts. Larger appliances, such as clothes dryers and electric cook tops, use 240 volts. The amperes might be stamped on the unit instead of the wattage. If there is no ampere listing, a clamp-on ammeter can be used, an electrician's tool that clamps around one of the two wires on the appliance, to measure the current flowing through the appliance. You can obtain this type of ammeter in stores that sell electrical and electronic equipment. Take a reading while the device is running; this is the actual amount of current being used at that instant. Also, when measuring the current draw of a motor, the start-up current of the motor is about three times larger than the running current (EREC, 2001).

Another factor to be considered is that some appliances still draw a small current even when they are turned off. 'These "phantom loads" occur in most appliances that use electricity, such as VCRs, televisions, stereos, computers, and kitchen appliances' (EREC, 2001). Phantom loads increase the appliances total load slightly. Unplugging the appliance or using a power strip and use the switch on the power strip to cut all power to the appliance can eliminate these loads.

4.1.5.4 Refrigerators

Refrigerators and freezers consume about a sixth of all electricity in a typical American home - using more electricity than any other single household appliance (California Energy Commission, 2002).

Federal efficiency standards are updated periodically to ensure that appliances continue to become more and more efficient. As a result of these new standards, the energy efficiency of refrigerators has improved dramatically.

A refrigerator's efficiency rating is based on the energy it consumes per year. For example, "the energy bill for typical new refrigerators with automatic defrost and top-mounted freezer will be about $55/year, whereas a typical model sold in 1973 will cost nearly $160/year" (DOE, 2001).

> Almost all of the energy used by a refrigerator is used to pump heat out; the rest is used to decrease sweating and frost, and to light the small light bulb inside. Although many energy-efficient products may cost more initially, they will pay for themselves in the long run.
>
> For example, a more expensive model could pay for itself in a little over three years. Over the 15-year lifetime, the more expensive refrigerator might save up to $750 (DOE, 2001).

There are also many ways to save energy by using different features on the appliance. Refrigerators with bottom freezers are the most efficient, followed by top freezer models, and side-by-side models are the least efficient. Through-the-door icemakers and water dispensers decrease the efficiency of the appliance and can increase the energy use by 14 to 20 percent (DOE, 2001). A manual defrost refrigerator, when defrosted regularly, uses much less energy than an automatic defrost model. Anti-sweat heaters consume a lot of energy and are not necessary.

> Brushing or vacuuming the coils in the back of a refrigerator can improve efficiency by as much as 30 percent. Refrigerators should be kept between 35 and 38 degrees Fahrenheit, a fridge that is 10 degrees colder than necessary can use 25 percent more energy.
> (California Energy Commission, 2002)

Federal law requires that Energy Guide labels be placed on all new refrigerators. These labels are bright yellow with black lettering. The Energy Guide label on new refrigerators will tell you how much electricity in kilowatt-hours (kWh) a particular model uses in one year. If a refrigerator is Energy Star rated it means that it meets an even higher standard than that imposed by the government.

Many factors determine the rate at which refrigerators cycle on and off. "These factors include how well it is insulated, room temperature, freezer temperature, how often the door is opened, if the coils are clean, if it is defrosted regularly, and the condition of the door seals" (EREC, 2001). To calculate an approximate figure of the number of hours that a refrigerator is running, divide the total time the refrigerator is plugged in by three (EREC, 2001).

4.1.5.5 Freezers

Freezer efficiency depends on the size and type of freezer. Chest freezers (top loading) are more efficient than upright freezers (front loading). They have better insulation and they don't loose all of their cool air when the door is opened (DOE, 2001).

"Manual defrost models consume 35-40% less energy than comparable automatic defrost ones, but periodic defrosting to keep ice build-up less than 1/4 inch is necessary to ensure energy efficiency" (DOE, 2001). Freezers are also required to have Energy Guide labels on them. Keeping freezers too cold can waste a considerable amount of energy; they should be kept at about 0 degrees Fahrenheit (DOE, 2001).

4.1.5.6 Clothes Dryers

Clothes dryers are not required to display Energy Guide labels because they do not vary much from model to model.

> A dryer is typically the second-biggest electricity-using appliance after the refrigerator, costing about $85 to operate annually. Over its expected lifetime of 18 years, the average clothes dryer will cost approximately $1,530 to operate. (California Energy Commission, 2002)

Right now, all dryers on the market work the same. They operate on 240-volt current. They dry clothes by tumbling them through heated air.

Another option is gas dryers; they cost approximately $50 more than the comparable electric model. But in most areas gas dryers will cost less to run over their lifetime. "Generally speaking, the cost of electricity needed to dry a typical load of laundry is 30 to 40 cents, compared to 15 to 20 cents if you use gas" (California Energy Commission, 2002).

The energy efficiency of clothes dryers is measured by a term called the "energy factor," which is a measure of pounds of clothing per kilowatt-hour of electricity. The rating 3.01 is the minimum energy factor for a standard capacity electric dryer, while the minimum energy factor for gas dryers is 2.67 (DOE, 2001).

A feature found on good dryers is a moisture sensing setting. Some models have sensors in the drum for sensing dryness, and other, cheaper models estimate dryness by sensing the temperature of the exhaust air. "Compared with timed drying, you can save about 10 percent with a temperature sensing control, and 15 percent with a moisture sensing control" (California Energy Commission, 2002).

4.1.5.7 Clothes Washers

Clothes Washers are one appliance where efficiency has increased dramatically in the last few years. Much of this is due to the new horizontal axis washers.

The majority of the energy used by clothes washers is used to heat the water (DOE, 2001). Little energy is used by the electric motor to spin the clothes washer. Therefore, the best way to improve the efficiency of a clothes washer is to reduce the amount of hot water that is needed to wash the clothes. Also, the effectiveness of the spin cycle of the clothes washer is important. The more effectively the washer drains water from the clothes during the spin cycle, the less energy is used by the clothes dryer to finish the job (DOE, 2001).

The efficiency of clothes washers is measured by a term called the energy factor (EF), which is a measure of cubic feet of washing capacity per kilowatt-hour of electricity. An EF of 1.18 is the minimum allowed energy factor, and Energy Star products have an EF of at least 2.5 (DOE, 2001). In the future, there will be a transition to a Modified Energy Factor (MEF), which will account for the remaining moisture in clothes (DOE, 2001). Faster spin speeds remove more water from the clothes and can be found on expensive models.

Since most of the efficiency benefits are related to the heating of water, washing clothes in cold water will save more energy than any other factor. Many washer models come equipped with user controls for wash and rinse temperatures and load size. Some models have a "suds saver" option, which saves the soapy water to be used in different cycles (DOE, 2001). There are some new washers that automatically adjust the water level and wash cycle to accommodate the size and type of each load. The use of all of these features correctly will dramatically improve washer efficiency.

New horizontal axis clothes washers are much more efficient than top loading models. With horizontal axis washers only the bottom of the drum is filled with water and the clothes are tumbled in and out of it (California Energy Commission, 2002). In top loading washers, the water level is raised high enough to immerse all of the clothes, which requires much more water than horizontal axis washers. This means that much less water is heated in horizontal, front-loading washers.

4.1.5.8 Ranges

Conventional ovens must heat up the entire interior of the oven before they actually work to cook the food. This space is made up of "about 35 pounds of steel and a large amount of air" (DOE, 2001). This means that most of the energy used by the stove is wasted in this process. Only a small percent of the energy output is absorbed by the food. Additional insulation and tighter-fitting door gaskets help to save energy on newer model ovens (DOE, 2001).

Self-cleaning ovens have more insulation than regular models. So for regular use self-cleaning ovens are more efficient because they allow less energy to escape from the stove. However, if the self-cleaning feature is used more than once per month the extra energy that can be saved will all be used up (DOE, 2001). Also, the self-cleaning feature should be used immediately after food has been cooked because the oven is already hot and less energy must be used to bring it up to cleaning temperature (DOE, 2001).

There are basically four different types of electric cook tops: solid disk elements, radiant elements under glass, halogen elements, and induction elements. Solid disk and radiant elements under glass are easier to clean, but they take longer to heat up and use more electricity. Halogen and induction elements are more efficient (DOE, 2001). The only drawback is that only iron and steel pots may be used with induction elements, aluminum cookware will not work. The cook top surfaces must be kept clean for them to reflect heat and better save energy. Flat-bottomed pans that are sized correctly with the heating element are necessary to have the highest efficiency. Pans must make full contact with the heating surface; warped and rounded pans will allow most of the heat to rise past the pan without using the energy (DOE, 2001). In addition, using a burner that is too big for the pan wastes heat energy by allowing heat to flow around the pan and not be used at all.

Preheating an oven also wastes energy. In most cases preheating is not necessary, if it is necessary the preheating time should be kept to a minimum (DOE, 2001).

Using ceramic or glass pans can increase efficiency. With these types of pans the temperature can be reduced by about 25 degrees and cook food just as fast (DOE, 2001). Using a pressure cooker is another way of saving energy. "By cooking food at a higher temperature and pressure, cooking time is reduced dramatically and energy use is cut by 50-75%" (DOE, 2001).

Opening the oven to look at the food results in the temperature of the oven dropping by 25 degrees each time (DOE, 2001); this means that the stove has to use more energy to bring the temperature back up, and it increases the cooking time. Also, small to medium sized meals should not be cooked in a full size oven; in these cases energy can be saved by using toaster ovens.

Another alternative is to use a gas oven. Gas ovens use much less energy than electric ovens. Gas ovens should be equipped with electronic ignition for energy efficiency (DOE, 2001).

4.1.5.9 Dishwashers

Dishwashers have also become more efficient than ever before; when operated at full capacity they can actually save more energy than washing by hand. They can save time and water when compared with washing by hand. Dishwashers come in standard and compact size. Obviously the compact size uses less energy; however if more washes are done to make up for the smaller size they actually waste energy in the long run.

As with washing machines, almost all of the energy that dishwashers use goes towards heating the water (DOE, 2001). Therefore, the best way to improve the efficiency is to reduce the amount of hot water needed to clean the dishes. Dishwashers used to use between 8 and 14 gallons of water per wash, where now they use only 7 to 10 gallons (California Energy Commission, 2002). New spray arms that provide better movement and improved filtering systems are a cause of decreased hot water use. Also, some new dishwashers have an air-dry cycle that can save energy.

Most new dishwashers use a built-in booster heater to bring the temperature of the water up to 140°F to kill germs. This obviously takes more energy to run, but if this feature is used it allows the temperature setting of the home hot water heater to be lowered down to 120 °F. "Each 10°F reduction in the water heater temperature setting will save up to 13% of your hot water heating bill and also reduce the danger of scalding" (DOE, 2001).

Dishwasher efficiency is also measured by a term called the energy factor, which is measured in cycles per kilowatt-hour of electricity. The smallest energy factor rating allowed by the government is 0.46. The DOE recommends that dishwashers use 555 kWh/yr or less with an energy factor of 0.58 or more (DOE, 2001). The best available dishwasher efficiency is 277 kWh/yr with an energy factor of 1.16 (DOE, 2001).

As with clothes washers, dishwashers can have many different wash cycle selections. Using a "light wash" or "energy-saving" wash cycle can save energy by using less water and operating for less time (California Energy Commission, 2002). Also, some dishwashers are able to allow the user to select between air-drying or heat-drying. The air-drying option uses much less energy that the heat drying. If a dishwasher does not have the air-drying option it should be stopped just before the drying cycle and have the door opened so the dishes can dry off naturally.

Dishwashers should always be operated with a full load in them because the dishwasher uses the same amount of water whether it is half full or completely full. Dishes should not be pre-rinsed before they are put in the dishwasher; the amount of energy used in pre-rinsing is more than the dishwasher would use, so it is wasteful. Food should be scraped off dishes before they are put in, and liquids should be drained off. If dishes must be rinsed, they should be rinsed in cold water. Also, the "rinse hold" feature should not be used for just a few soiled dishes because it uses a lot of water each time (DOE, 2001).

4.1.5.10 Air Conditioners

4.1.5.10.1 Central AC

Air conditioners satisfy three functions to cool your house: remove hot air from the house and bring it outside, distribute cool air in the house, and remove moisture from indoor air. There are two basic types of air conditioning units; compressor-driven air-conditioning systems and evaporative coolers. Evaporative coolers are only practical in hot, arid regions such as the southwest, while compressor-driven systems work better in most other areas (DOE, 2001).

U.S. law and the U.S. Department of Energy restrict the efficiency of central A/C units. Air conditioners are given an efficiency rating called a seasonal energy efficiency ratio (SEER). "The SEER is defined as the total cooling output (in Btu-British thermal units) provided by the unit during its normal annual usage period divided by its total energy input (in Watt-hours) during the same period" (DOE, 2001). This number is displayed on the Energy Guide label on the A/C unit.

> The minimum SEER allowed by law for a central A/C is 10 for a split system or 9.7 for a single-package unit. The best available SEER is about 18, while many older units have SEER ratings of 6 or less. A SEER of 12 or higher is a desirable efficiency.
> (DOE, 2001)

Dirt build-up on the indoor coil of the A/C is a large cause of inefficiency. Therefore, indoor coils should be cleaned on a regular basis (California Energy Commission, 2002). Additional features for air conditioners can also help save energy, such as a fan-only feature that can be used at nighttime for ventilation; when using this, the house should be kept closed tight during the day. Also, bath and kitchen fans should not be used while the air conditioner is in use, as they will pull the cool air out of the house and pull warm, moist air in. Thermostats should be set at 78° F or higher. "Each degree setting below 78 F will increase energy consumption by approximately 8%" (DOE, 2001). Windows should be shaded on the east and west sides of the house to block heat from the sun. Finally, do not cook or use the dishwasher while the AC is working; it will add extra heat to the house and cause the AC to work harder to bring the temperature down.

4.1.5.10.2 Room Air Conditioners

Room air conditioners work basically the same way as central A/C's do, but on a smaller scale. There are three types of room A/C's, which include normal window models for double hung windows, casement window models for odd shaped windows, and built-in models that require a hole to be cut in the house and a sleeve installed to house the A/C unit (California Energy Commission, 2002).

Room air conditioners should be sized properly for the given room in order to operate efficiently. The right size A/C for a given space can be calculated, given that it takes approximately 20 Btu for each square foot of living space (DOE, 2001).

> An average air conditioned home consumes more than 2000 kilowatt-hours of electricity per year for cooling, causing about 3,500 pounds of

> carbon dioxide and 31 pounds of sulfur dioxide to be emitted by the power plant. At average electricity prices, that costs about $150. A high-efficiency A/C unit can reduce energy consumption (and environmental emissions) by 20% to 50%. The most efficient air conditioners on the market are up to 70% more efficient than the current average room air conditioner.
> (DOE, 2001)

U.S. law and the U.S. Department of Energy regulate the efficiency standard for room air conditioners. They use a rating called the energy efficiency ratio (EER), which is the cooling output divided by the energy input. They require an EER of between 8 and 9 depending on the unit, and the best available EER is 13 (DOE, 2001). The EER is displayed on the Energy Guide label on the A/C unit.

There are many ways to increase the efficiency of an A/C unit. The filter must be cleaned or replaced regularly, and the drainage channels must be kept free of obstruction at all times. Also, placing the unit in the shade keeps the heat from the sun from affecting the compressor motor and increases efficiency (DOE, 2001).

If it is possible to substitute fans for air conditioners a significant amount of energy can be saved. Indoor fans can also be used to help assist an air conditioner in moving the cool air around the room. Getting a programmable thermostat to turn up the temperature during times when the A/C is not necessary can save energy (California Energy Commission, 2002). The heat from some appliances can cause a thermostat to read incorrectly and make the A/C run longer than it has to. Therefore, heat generating appliances or light bulbs should not be placed near the thermostat.

4.1.5.11 Heat Pumps

Heat pumps use less energy than space heating furnaces and can also work to replace air conditioning by cooling the home. Their biggest drawback is that they can only be used in mild to moderate climates, because if it is too cold outside they will not work at all (DOE, 2001). To operate, they take heat from outside sources and bring it inside the house, or they can collect the heat from inside the house and bring it outside. Heat pumps can take heat from three different areas: air source, water source, and ground source.

The efficiency of heat pumps is measured by the heating season performance factor (HSPF), which consists of the seasonal heating output divided by the seasonal power consumption. When the heat pump is in the cooling mode its efficiency is measured just like a central air conditioner, with the seasonal energy efficiency ratio (SEER) (DOE, 2001). The HPSF ratings have a minimum of 6.8 and the most efficient models have a rating of 10.0, while the SEER ratings have a minimum of 10.0 and the most efficient models have a rating of 14.0 (DOE, 2001).

Ground source heat pumps are more expensive to install than air source heat pumps, but they are also more efficient and may save more energy in the long run.

Unlike air conditioners, changing the thermostat temperature at night will not save energy; in fact it will use even more. This is because when the heat pump turns back on in the morning it takes more energy to get it back up to the desired temperature than it would have taken to simply leave it on all night (DOE, 2001). If the system is equipped with a fan it should be set to the "auto" fan setting so the fan does not run all the time. As with air conditioners, filters should be cleaned or changed periodically to ensure good airflow through the system.

4.1.5.12 Space Heating

Space heating furnaces are expensive to operate on a yearly basis, but they have had many improvements. Some models can even achieve an efficiency rating of 100% (DOE, 2001). Improving the efficiency of your space heating can be good for the consumer as well as for the environment, by reducing the amount of polluting byproducts emitted by the furnace.

> Space heating is the largest energy expense in most homes, accounting for two-thirds of annual energy bills in cold climates. Heating systems in the United States emit a billion tons of carbon dioxide (CO_2) and about 12% of the sulfur dioxide and nitrogen oxides emitted by the nation. Reducing energy use for heating is the single most effective way to reduce a home's contribution to global environmental problems. Conservation efforts and a new high-efficiency heating system can often cut your pollution output and fuel bills in half. Upgrading your furnace or boiler from an AFUE (annual fuel utilization efficiency) of 56% to 90% in an average cold-climate house will save 1.5 tons of CO_2 emissions if you heat with gas or 2.5 tons if you heat with oil and will cut your heating bill by almost 40%.
> (DOE, 2001)

The efficiency rating for a furnace or boiler is called the annual fuel utilization efficiency (AFUE), which is given in percentage form. Indoor all-electric furnaces do not have any heat loss and are able to achieve AFUE ratings of between 95% and 100% (DOE, 2001).

There are minimum AFUE ratings for different types of furnaces that have been set by the U.S. Department of Energy in the National Appliance Energy Conservation Act of 1987 (DOE, 2001). "The minimum allowed AFUE rating for a non-condensing, fossil-fueled, warm-air furnace is 78%; the rating for a fossil-fueled boiler is 80%; and the rating for a gas-fueled steam boiler is 75%" (DOE, 2001). Condensing units have a higher AFUE rating than non-condensing units. They are more expensive to buy but they will save money in the long run, due to their better efficiency (DOE, 2001).

When dealing with gas or oil heaters, sealed combustion heaters are better than non-sealed as far as efficiency goes (DOE, 2001). They bring outside air straight into the burner and they expel combustion gasses straight outside. This makes a draft hood or a damper unnecessary and increases the home's safety because there is no risk of dangerous gasses being let into the home.

The most energy is consumed when the heater is fired up, so the temperature setting should be kept relatively constant to reduce the cycling on and off of the furnace (DOE, 2001). Also, shades or drapes should be used on south, east and west sides of the house. They should be open while the sun is on them and closed at all other times during the cold seasons (DOE, 2001). This will let in heat from the sun when they are open, and help prevent cold air from getting in when they are closed.

Unused rooms should be closed off and not heated. Kitchen and bathroom vent fans should be used sparingly, as with air-conditioned houses (DOE, 2001). They will pull the warm air out of the house and waste the energy used by the furnace.

Here are some statistics from the BTS Core Databook (1996):

Table 4.1 Average Life of Heating Sources

Fuel	Average Life	Units Replaced (1996)
Electric	17 Years	284,300
Gas-Fired	18 Years	1,637,900
Oil-Fired	16 Years	63,700

(DOE, 2001)

4.1.5.13 Water Heaters

A water heater's efficiency is measured by its energy factor (EF). "Electric resistance water heaters have an EF ranging from 0.7 to 0.95; gas water heaters from 0.5 to 0.6, with a few high-efficiency models ranging around 0.8; oil water heaters from 0.7 to 0.85; and heat pump water heaters from 1.5 to 2.0" (DOE, 2001).

Water heaters also have what is called a first-hour rating (FHR), which is listed on the Energy Guide label on each appliance (DOE, 2001). The FHR measures how much hot water the water heater can produce during a time of day that requires the most hot water. This value is usually more important for performance than any other factor. For maximum efficiency, the peak-hour demand for a house should be determined and then the water heater with the correct FHR for that demand should be chosen (DOE, 2001).

Natural gas, oil and propane water heaters are less expensive to operate than electric models, but some utility companies offer off-peak electricity rates for water heating which may bring down the price enough to be cost efficient (DOE, 2001).

For the highest efficiency, water heaters should be installed in heated areas of the house (DOE, 2001). Also, the lengths of piping going to the bathrooms and kitchens should be minimized (DOE, 2001). Low-flow showerheads and faucets can cut back on hot water use and, subsequently, energy use. Leaky showerheads and faucets can waste a lot of hot water and should be fixed.

The thermostat on water heaters should be set to 120° F. Timers can be installed to shut off electric water heaters during the night, which prevents the heating elements from cycling on and saves energy. A heat trap can also be installed above the water heater to prevent hot water from creeping up into the pipes when it is not needed and dissipating the heat (DOE, 2001).

The water in the lower part of the heating tank should be drained periodically to remove sediment from the tank. The sediment, if left in the tank, can restrict heat transfer and lower the unit's efficiency (DOE, 2001). Finally, showers should be taken instead of baths, as baths use more hot water.

4.1.5.14 Miscellaneous Appliances

"About 18% of all U.S. residential electricity, or 1600 kWh/yr per household, is used for miscellaneous appliances" (Meier, Rainer, and Greenberg, 1992). There is not a standard definition of a miscellaneous appliance, so the few studies that have been done on the subject vary in their interpretation of what to include. Where one study listed miscellaneous appliance energy use at 41% of a household, another study had the energy use listed as 0% (Meier, Rainer, and Greenberg, 1992).

The following table from Energy, May 1992, lists the national saturation (or percentage in each house) and unit energy consumptions (UEC) of 35 miscellaneous appliances.

Table 4.2 Nationwide Miscellaneous Energy Use

End Use	Stock (Millions)	UEC (kWh/year)	National Consumption (TWh/year)	Percent of Total Household
Furnace Fan	45	500	22.5	2.78
Color TV	87	250	21.8	2.69
Waterbed Heater	14	900	12.6	1.56
Microwave Oven	72	120	8.6	1.07
Dishwasher	36	200	7.2	0.89
Pool Pump	4	1500	6	0.74
Aquarium	10	548	5.5	0.68
Crankcase Heater	27	200	5.4	0.67
Spa / Hot Tub	2	2300	4.6	0.57
Clock	180	25	4.5	0.56
Well Pump	11	400	4.4	0.54
Dehumidifier	11	400	4.4	0.54
Toaster	86	50	4.3	0.53
Audio System	81	50	4.1	0.5
Hair Drier	85	40	3.4	0.42
Blanket	27	120	3.2	0.4
Vacuum	90	30	2.7	0.33
Ceiling Fan	54	50	2.7	0.33
Grow-Lights	3	800	2.4	0.3
VCR	59	40	2.4	0.29
Coffee Maker	36	50	1.8	0.22
Black and White TV	45	40	1.8	0.22
Computer	13	130	1.7	0.21
Iron	32	50	1.6	0.2
Humidifier	11	100	1.1	0.14
Engine Heater	4	250	1	0.12
Exhaust Fan	54	15	0.8	0.1
Whole House Fan	8	80	0.6	0.08
Sump/Sewage Pump	13	40	0.5	0.06
Garbage Disposer	40	10	0.4	0.05
Heat Tape	3	100	0.3	0.04
Bottled Water Disp.	1	300	0.3	0.04
Window Fan	9	20	0.2	0.02
Mower	5	10	0.1	0.01
Instant Hot Water	0.5	160	0.1	0.01
Total Misc.	--	1610	145	18
Total Household	90	8978	808	100

Another table from <u>Energy</u>, May 1992 is shown here. This table lists nationwide residential miscellaneous electricity use in descending order.

Table 4.3 Ranges for Appliances

End Use	National Saturation, Min. - Max.	UEC (kWh/year) Min.-Max.
Aquarium	.05-.15	200-1000
Audio Systems	.70-.90	10-100
Black & White TV	.50-.60	10-100
Blanket	.25-.35	70-200
Bottled Water Disp.	.01-.02	200-400
Ceiling Fan	.20-.40	10-150
Clock	1	17-50
Coffee Maker	.30-.50	20-300
Color TV	.96-.99	75-1000
Computer	.10-.20	25-400
Crankcase Heater	.25-.35	100-400
Dehumidifier	.10-.13	200-1000
Dishwasher	.38-.45	75-500
Exhaust Fan	.30-.60	2-70
Engine Heater	.02-.06	150-800
Furnace Fan	.45-.60	300-1500
Garbage Disposer	.40-.50	20-50
Grow-Lights	.02-.05	200-1500
Hair Driers	.70-1.00	10-80
Humidifier	.08-.15	20-1500
Instant Hot Water	.005-.02	100-300
Iron	.20-.40	20-1500
Microwave	.70-.90	50-300
Mower	.05-.08	5-50
Heat Tape	.02-.05	30-500
Pool Pump	.04-.06	500-4000
Spa/Hot Tub	.01-.05	1500-4000
Sump/Sewage Pump	.10-.20	20-200
Toaster	.90-1.00	25-120
Vacuum Cleaners	.90-1.20	5-50
VCR	.60-.70	10-70
Waterbed Heater	.12-.20	500-2000
Well Pump	.05-.20	200-800
Whole House Fan	.08-.10	20-500
Window Fan	.05-.15	5-100

As more and more electronic appliances are being manufactured and gain popularity, there are more and more appliances that fall into the miscellaneous category. For example, televisions, VCR's, DVD players, and surround sound systems are becoming more common and will have to be added to the list of miscellaneous appliances.

Although miscellaneous end use is not well defined, it still must be addressed when calculating a household electricity load. If it is overlooked, the calculations for all other major appliances will have to be too large in order to absorb the error for leaving miscellaneous appliances out.

4.2 Survey Literature

4.2.1 Question Writing

The first step in designing a questionnaire which will insure reliable results is determining the information necessary from the respondents. Typically, questions are grouped into two different categories, behavior and attributes, and attitudes and beliefs (Salant and Dillman, 1994).

When questions are categorized as asking about attitudes and beliefs, they are typically asking the respondent to indicate their opinions, behavior and attributes questions typically ask people to indicate what they do in a particular situation (Selltiz, Wrightsman, Cook, 1981). All of the questions that fit in these categories can be asked in four different manners: open-ended, closed-ended with ordered choices, closed-ended with unordered choices, and partially closed-ended. There are positives and negatives to using either type of question.

Open-ended questions typically require the largest amount of effort, on the part of the respondent and the part of the surveyor. Respondents may not wish to take the time necessary to first formulate an answer and then fill out the form (Salant and Dillman, 1994). The problems on the part of the surveyor are related to this as well. The range of answers supplied for an open-ended question is typically quite broad, making the cataloguing and analysis of the data extremely difficult (Salant and Dillman, 1994). Despite these difficulties, open-ended questions, when used correctly, can be quite effective. Responses to open-ended questions may bring to light opinions or viewpoints that the surveyors overlooked (Rosnow and Rosenthal, 1993), or can be used to clarify responses to closed-ended questions (Salant and Dillman, 1994). Typically, open ended questions are necessary where more information is needed than can be gleaned from a list of provided answers (Salant and Dillman, 1994).

The polar opposites of open-ended questions are the categories of closed-ended questions. In a closed-ended question, the surveyor gives the respondent the option of indicating a number of different pre-selected responses. There are two pure types of closed-ended questions, those with ordered choices, and those with unordered choices. Ordered-choice closed-ended questions give the respondent the opportunity to indicate the degree of their response (Groves, 1989). In unordered-choice questions, the respondent is simply asked to indicate an answer in a list of unordered choices (Groves, 1989). It is important to note that these questions must be used properly; unordered responses can be more difficult for respondents to answer (Salant and Dillman, 1994).

The middle ground between open-ended and closed-ended questions is partially closed-ended questions. Partially closed-ended questions offer an unordered list of pre-selected responses for the respondent to choose, or the option of indicating a different response in a different field, if they feel the pre-selected responses aren't suitable (Fowler, 1988).

In mail-in surveys, the surveyor does not have the ability to pace the actions of the respondent, and they may simply glance at the question and indicate an answer; this can lead to error in the survey (Salant and Dillman, 1994). In addition, other error can be generated depending on what is asked: attribute and behavior questions usually do not generate significant error (Groves, 1989); while questions on attitudes and beliefs can be the cause of significant error (Salant and Dillman, 1994). To minimize the error for all questions, the survey designers must think carefully about the wording of each question, and design the questions to fit with one another (Salant and Dillman, 1994)

4.2.2 Questionnaire Design

Once the questions for the questionnaire have been designed, the remaining task in designing the actual survey is the physical layout of the questionnaire. A sound questionnaire design "minimizes respondent burden (Fink, 1995)," or makes the questionnaire easier to answer for the respondent.

The different types of surveys given all depend on different methods of communication. Thus, questionnaires will be designed different for face-to-face interviews than mail in surveys, and vice versa. The first responsibility of a mail-in survey designer is to create a design which will encourage recipients to respond (Salant and Dillman, 1994).

Some guidelines for the design of a mail-in questionnaire include: clear and concise instructions, simple questions, and a catchy cover page (Selltiz, Wrightsman, and

Cook, 1981). In addition, a title that is effective in communicating the content of the survey will also go a long way towards increasing response (Salant and Dillman, 1994).

The cover page, which may or may not be part of the survey itself, is extremely important because it is what the recipient will see first. One effective method of getting the recipients attention is by including a cover letter. If chosen, the cover letter should include the purpose of the study, the organization responsible for the study, and a return address where the surveyors may be contacted (Salant and Dillman, 1994).

An important guideline to follow when deciding which questions should be located where is to group similar questions together (Selltiz, Wrightsman, and Cook, 1981). In addition, questions on similar topics should be structured in similar manners, to 'ease the respondents' transition from question to question (Salant and Dillman, 1994). This technique is generally referred to as vertical flow (Salant and Dillman, 1994). Finally, the last technique mentioned to help respondents delineate questions and answers was to put the questions in bold face type and the answers in standard type (Fowler, 1988).

The last important method for improving the survey is to pretest the survey before it is used to obtain actual data. Pretesting can bring to light specific problems with questions which may have been unanticipated by the survey designers (Selltiz, Wrightsman, and Cook, 1981).

4.2.3 Sampling

While the design of specific questions and the layout of the questionnaire are important in reducing error in a survey, accurate sampling is just as crucial. Because one cannot hope to survey an entire population if that population is sufficiently large, sampling techniques are used to accurately predict the responses of that population, but through the survey of a smaller number of subjects (Fowler, 1988). Generally, there are three steps involved in sampling

The first step involved in sampling is determining the target population for the sample. This generally involves deciding whether or not a group of people would be valuable to your study results (Selltiz, Wrightsman, and Cook, 1981). The second step in sampling is to determine the actual population the sample will be drawn from. This section, called the list frame, is determined using the target population found in step one (Fowler, 1988). Finally, the last step involved in sampling is to select the sample from the population specified in step two (Fowler, 1988). A number of different methods for sampling a population exist, including simple random sampling, and stratified random sampling.

In simple random sampling, a sample is selected from a population completely randomly, taking into account no other factors (Rosnow and Rosenthal, 1993). Very similar to simple random sampling is stratified random sampling; however, in stratified random sampling, the population is divided into strata based on specific characteristics, and a simple random sample is taken from each strata (Groves, 1989). It is generally felt that stratified random sampling reduces sampling error (Groves, 1989). Finally, determining the number of subjects to include in your sample depends on the amount of error the surveyor is willing to accept (Salant and Dillman, 1994).

4.2.4 Insuring a High Response Rate

Based on the research we have reviewed, a well designed mail-in survey with a personalized cover letter should receive approximately a 60% response rate (Salant and Dillman, 1994). Some suggestions to improve the response rate of a survey are performing several follow-ups (Fowler, 1988), and maintaining a subjects anonymity throughout the process (Fowler, 1988). In the first follow approximately ten days after the initial mailing, all subjects should be sent a card thanking them for their participation in the survey, and reminding them to return the survey. The second follow-up should be sent only to individuals who have not returned their survey, and should include a second copy of the survey for their perusal (Fowler, 1988). Finally, instead of putting the subjects address on their survey, simply include an identification number to determine when specific surveys have been returned (Groves, 1989). While a respondent's particular survey can be tracked back to them, it requires effort, and thus assures the respondent some degree of anonymity.

4.3 Bill Usability Literature

Usability testing is an important way for interface and document designers to test the effectiveness of their designs. It is for this reason we have decided to attempt a redesign of the Mass. Electric power bill through the use of such a study. When we originally began searching for literature on the usability of power bills, we were surprised at our lack of results. However, after talking with a technical writer, we learned that very few usability studies are done on short documents, such as invoices or bills, but are targeted more to documents such as user-guides and such. He suggested we look on a number of websites, as well as search a number of databases which were linked to the WPI library website.

Table 4.4 Terms Searched for Bill Usability Studies

Bill Usability Design
Bill Usability Testing
Bill Usability
Invoice Usability Design
Invoice Usability Testing
Invoice Usability

After a review of the websites we were directed to, we emerged empty handed. Following the second piece of advice, we attempted to search several databases on the WPI library, all of these databases returned negative results. Table 5.4 indicates the terms we searched for in each of the databases, while table 5.5 is a brief list of several of the comprehensive usability websites and journal databases we searched. The final piece of advice given to us by this technical writer was in the absence of bill usability information, we should purchase several books on usability testing and document design. These books, "Dynamics in Document Design," and the "Handbook of Usability Testing," were invaluable in our design of the usability test.

Table 4.5 List of Sites Searched for Bill Usability Information

Usability Websites	**Site**
User Interface Engineering	www.uie.com
Usability Information Technology	www.useit.com/
Usability Special Interest Group	www.stcsig.org/usability
Usability Professional's Association	www.upassoc.org
General Databases	**Site**
J-Stor	www.jstor.org
Office of Science and Technology Information	www.osti.gov/energycitations/
OGLC FirstSearch	newfirstsearch.oclc.org/
Wiley InterScience	www3.interscience.wiley.com
Knovel, Engineering and Scientific Online Resources	www.knovel.com,
Science Direct	www.sciencedirect.com

In addition to the use of the books mentioned above, we also borrowed a technique used in a Sun Microsystems usability study commonly referred to as "Discount Usability Testing." The study, written by Jakob Nielson and Darrel Sano (1994) was one of the first studies to extensively use this new technique. We learned of this type of testing in an article published by Sun. They set out to make a new internal internet interface that allowed their employees to access important information and documents, but wanted the design to be as problem-free as possible when it was released. At this time Sun was growing at a huge rate, and the internet on the whole was growing at about 10000% new web servers every year. Because Sun's original internal website was fragmented and complicated, and more employees were relying on it every day, time was of the essence.

The team responsible for the interface design determined that they would want to use "discount usability engineering." This is a method that is deliberately informal and relies less on statistics and more on the engineers' ability to observe the users and interpret the results. They did four studies: The first was a card sorting to discover what sub-categories of information should be grouped together, under larger categories. The second was an icon intuitiveness which just tested what different people associated with certain icons. The third study, a study of card sorting distribution to icons, brought together the first two studies. The fourth and final study was a thinking-aloud walkthrough of the proposed page design. A large number of problems the engineers had not anticipated were solved, even though they used only three people to accomplish their study.

5 Methodology

5.1 Introduction

In examining the literature review, there are many different possibilities available to us which might enable us to determine the amount of electricity wasted by consumers, and to help consumers save money. The best method for determining how much electricity is used by consumers within our means is to create a study similar to Parti and Parti. Through the use of direct surveys of customers, obtain appliance ownership information, and then correlate that data with electrical usage information from the power company.

The most intriguing possibility for helping consumers save energy was mentioned briefly in Battalio, et al. (1979); feedback daily or every other day has reduced electrical consumption upwards of 15% in some studies. Whether this is attributed to the fact that the consumer is more educated about their consumption, or simply the 'Hawthorne Effect,' is not mentioned. The Hawthorne Effect is the "Initial improvement in a process of production caused by the obtrusive observation of that process (PCW 2002)." It is our opinion however, that the more educated a consumer is about his consumption, the more likely he is to try and conserve energy. This being given, providing daily feedback to the consumer would help him save electricity in a relatively easy and hopefully inexpensive manner.

Our last goal, helping consumers understand their power bills, was not addressed by conventional literature, and is best solved by creating and running a usability study. Usability studies examine the interaction between the user and the product, in this case the customer and the electric bill. They are run to determine problem areas with the design of the bill, and to help guide developers to the solution of those problems. Based on the results of the usability study, we will be able to recommend changes for the bill, design a guide, or possibly both.

To present this section with clarity, we have divided up the tasks which must be completed by the goals they are intended to help accomplish. For instance, in order to accomplish the goal of "Helping consumers better understand their power bill" we must run a usability study, so "Usability Study" will be one of the topics in that section. In some cases there will be overlap between sections; for instance, surveying Massachusetts Electric customers will provide us information for all three main goals: how many appliances people own, whether or not people understand their electric bills, and whether or not people are interested in other methods to conserve electricity. In either case, this section is intended to spell out in detail how our goals will be accomplished.

5.2 Goal 1: Determining how much electricity is wasted on average

5.2.1 Introduction

As mentioned above, the most feasible method for us to determine how much electricity is wasted by a consumer on average is direct survey combined with KWh data. Thus, this section is split into two different sub-sections: survey methodology, and Massachusetts electric data. In order to ensure some reliability in our data, several guidelines must be followed: sound survey design, and reliable analysis of the data.

5.2.2 Direct Survey

5.2.2.1 Introduction

Following what was discussed earlier, we feel that one of the most important aspects of this project is a direct survey of customers. The information we need to gather, the design of the survey, and how the survey will be given are all concerns which we have chosen to address with this section.

5.2.2.2 Determine the necessary information

The first step in designing our survey was to determine the information we needed in order to accomplish the goals we established for the project. Because this project was initially based on receiving data from Massachusetts Electric Company, we felt the most important part of this survey was appliance ownership information, similar to the work by Parti and Parti (1978). The rest of the information we felt was important included opinions on conservation, some brief demographic information, and opinions on the power bill.

5.2.2.2.1 Demographics

Demographic information on the users taking the survey is important for a number of reasons. The most important part of demographics is the number of individuals living in a particular house. Electricity is based almost entirely on usage, and the more people in a house, the more often appliances are used. Other information we needed to know was how long they lived in the houses, and the gender of the people in each house.

5.2.2.2.2 Appliance Information

This data was by far the most important on our survey. By collecting appliance information, we are able to correlate the Massachusetts Electric Company data with the survey information to determine the amount of wasted electricity. The appliances we used for this section are based on the lists of appliances frequently mentioned in the literature, and the structure was generally made as simple as possible.

5.2.2.2.3 Opinions of Bills

The third class of information we felt it was important to ask about on our survey related more to our second goal than this first goal, but we felt the survey was a good place to begin addressing it. This particular section will attempt to get opinions (rather than fact, as was the case with the first two section) on the Massachusetts Electric Company power bill, in order to determine whether or not it should be redesigned, and/or whether or not a guide should be designed to make the bill easier to understand.

5.2.2.2.4 Opinions of Conservation

The fourth and final class of information to be obtained from the survey related to the respondents' opinions on particular practices of conservation. This section contains questions that will be related to both facts and opinions from the respondents. This is the section we will use to ask the respondents of their interest in a device to gauge the usage of electricity (which will be discussed in detail in relation to goal number three).

5.2.2.3 Determine Specific Questions

In order to obtain the information we feel can be gleaned from the survey of Massachusetts Electric Company customers, and to ensure the reliability of that data, the questions must be designed according to rigorous standards outlined in the literature, which we have summarized in the literature review. The questions should be designed as simply as possible, in order to minimize confusion among respondents, as well as minimizing the time required to complete each survey.

5.2.2.3.1 Demographics

The first section of the survey asked questions about demographics. This section is to find out more about the consumers, which might help us discover other factors that relate to the waste of energy. Demographics questions include facts about age, race/ethnicity, education, job, gender, marital status, number of children, place of residence, and type of residence.

5.2.2.3.1.1 Ages

Determining the age and the number of people living in the house is very important in the survey. This question might help us determine if age plays a role in the conservation of electricity. This question will also help us determine if the number of people in the household makes a difference in wasting electricity. This is a closed-ended question with numerical response choices.

1. Please note how many people live in the house from each age groups:

Under 10	10-25	25-35	35-50	50-65	over 65
______	______	______	______	______	______

5.2.2.3.1.2 Gender

The gender of each of the residents may also play a significant role in the wasting of electricity. Whether or not there is more of one gender than the other gender in the household may make a difference. This question is also closed-ended with numerical response choices.

2. Please note the number of people of each gender currently living in the house:

Male	Female
_____	_______

5.2.2.3.1.3 Years in House

It may be important to find out how long the respondent has lived in his house. Respondents who have lived in their houses for shorter periods of time might have newer and therefore more energy-efficient appliances. The third and final question asks how long the family has lived in the house and also is closed-ended with numerical response choices.

3. How long have you lived in the house? ______ years

5.2.2.3.2 Appliance Information

5.2.2.3.2.1 Electric Heat

The most important appliance information to obtain, which should be obtained at the beginning of the section, is whether or not the respondent has electric heat. In New England, electric heat is going to be one of the most costly contributors to the electric bill. This question is a closed-ended yes/no question, allowing the respondent to indicate whether or not he uses electric heating (be it a space heater, or central electric heating).

1. Do you have electric heat and/or electric space heaters? (Disregard Gas or Oil Heat)

Yes No

5.2.2.3.2.2 Air Conditioning

The other extremely costly appliance with regard to power usage, next to the electric heater, is the air conditioner. Therefore, determining whether or not the respondent has air conditioning is important. In addition to this, central air conditioning and window air conditioning behave differently, so it is necessary for us to distinguish between the two. Both of these questions are closed-ended questions. The first question, number 2, is a yes/no question, and a follow-up question, number 2b, is a closed-ended question with unordered responses (the options are related, but not on a spectrum or continuum).

2. Do you have air conditioning?

Yes No

2b. If yes, is it window, central, or both?

Window Central Both

5.2.2.3.2.3 Electric Range/Oven

Following Air Conditioning and Heating, there is a gap in the consumption of energy by appliances. One of the appliances in this less energy-demanding group is the stove, including both the stovetop range and oven. Therefore, it is necessary for us to determine which of these devices the customer owns, and if those devices are powered by electricity. Rather than ask two questions regarding whether or not they owned the device, and then how it was powered, we chose to lump the two questions together. This question is a closed-ended question, with four unordered possible responses.

3. Do you have an electric range/oven? (Disregard Gas Ranges/Ovens)
Electric Range   Electric Oven   Both
No/Different Power

5.2.2.3.2.4 Electric Hot Water

Another of the relatively constant expenditures on an electric bill is the cost of running an electric hot water heater. Because hot water consumption can be based on the number of family members living in the house, this question's answer can be partially combined with one of the questions asked in the demographics section. This question, like the majority of those on this survey, is a closed-ended yes or no question.

4. Do you have an electric hot water heater?
Yes   No

5.2.2.3.2.5 Washer and Dryer

The fifth question in the appliance section of the survey is similar to the fourth question; the usage of these devices depends at least in part on the number of people in the specific household. Obviously, if the person owns a washing machine, it is guaranteed to be powered by electricity. This is not necessarily true with dryers, which can also be heated using gas. Regardless, the dryer uses some electricity to provide the spinning motion. Therefore, it is important for us to determine first whether or not the respondents own a washing machine and dryer, and second whether or not the dryer is gas or electric. Both of these questions are closed-ended unordered response questions: the first is in a yes or no format, and the second provides the choice between a gas or electric power dryer.

5. Do you have a washer and dryer?

Yes No

5b. Is the dryer electric or gas?

Electric Gas

5.2.2.3.2.6 Refrigerators and Freezers

Unlike the previous two questions, the electric consumption of refrigerators and freezers does not depend on the number of individuals in the house, but rather the number of units in use. The cost of running these two appliances is almost constant through the year, due to the fact that they are virtually always on (though the cooling units cycle on and off, the appliances are rarely if ever actually turned off by the user). Therefore, this question cannot be designed like the majority of the other questions on this survey. The question will be structured as an open-ended question, leaving blanks for the respondent to enter the number of refrigerators and freezers he owns; this will allow us to better factor in the amount of energy used by each home.

6. How many refrigerators and freezers do you own?

___refrigerators ___freezers

5.2.2.3.2.7 Pools and Jacuzzis

The final appliances we have decided to include in our survey from the 'second tier' energy-requiring appliances are swimming pools and Jacuzzis. Like the previous question, the energy usage of both swimming pools and Jacuzzis doesn't depend on the number of occupants of the household, but the usage patterns of the appliances. Pools and Jacuzzis, though a similar kind of appliance, use energy in different ways. Pool and Jacuzzi filters cycle on and off during the time of year the pool is in use; in addition, depending on whether or not the pool or Jacuzzi is heated, greater energy consumption can be observed. For this question, we have decided to ask the respondents which of the two appliances they own in a closed-ended question with four possible responses. The second question, a follow-up to the first, is to determine how often the appliances are used throughout the year (this is because consumption should only be assumed when the pool or Jacuzzi is in use).

7. **Do you have a pool or Jacuzzi?**
   Pool Jacuzzi Both No
   7b. If yes, does it/they run all year?
   Both Only One Neither

5.2.2.3.2.8 Workshop

The final question in the appliance information section of the survey, although it was rarely mentioned in the literature, was designed to catch so-called 'wild cards' in the electrical usage information. Appliances of this nature, such as wood and metal working tools, often require a large amount of electricity when they are being used. In terms of appliance usage, this may not necessarily use as much energy as other devices we have chosen to leave off; the ownership information for these types of appliances is more valuable than others. We can assume that almost every house on our list has a television, whereas a workshop is not as likely for the respondents to have. Because we simply want to know whether or not they own a workshop, this question is designed to be a closed-ended yes or no question.

8. Do you have a 'workshop' (i.e. a place for wood or metal working)?

Yes No

5.2.2.3.3 Opinions of Bills

The consumer's opinion of his electric bill is a very important piece of information in our study. In this case, one of our project objectives was converted into various survey questions. The consumers' opinions of their bills will help us determine whether changes to the bill should be made.

5.2.2.3.3.1 Bill Estimated or Read

Finding out whether the consumer knows if his bill was estimated or read lets us know if he pays attention to and can understand his bill. This question is a closed-ended question with yes or no response choices.

1. **Do you know off the top of your head if your last bill was estimated or read? (simply yes or no, we just want to know if you remember either way)**

Yes No

5.2.2.3.3.2 Understanding the Bill

Knowing whether or not the consumer understands his electric bill is an important part of our analysis. If the consumer doesn't understand his bill, then he may be interested in a guide to the bill, or even a total redesign of the layout of the electric bill. Furthermore, if the consumer doesn't understand his bill, he may be wasting valuable electricity and not know it. This question is also a closed-ended question with yes or no response choices.

2. **Would you say that you understand your power bill (e.g., which parts can be controlled and which parts cannot)**

Yes No

5.2.2.3.3.3 Consumer Guide

Determining whether the consumer is interested in a guide to his power bill has a direct effect on one of our objectives. Depending on the outcome of the question, we may design a guide to the power bill. If a guide is designed, this may help the consumers better understand their power bills, which may have a direct effect on their wasting of electricity. The format of this question is also closed-ended with yes or no response choices.

3. **Would you be interested in a guide to help consumers better understand their power bills?**

Yes No

5.2.2.3.3.4 Redesign of the Power Bill

If the consumer doesn't understand his power bill, or is interested in a guide to his bill, then he may be also interested in a total redesign of the layout of the bill. The outcome of this question will also have a direct effect on one of our objectives. Depending on what this outcome may be, we will redesign the layout of the power bill, or at least make revisions. The final question to this section is also closed-ended with yes or no response choices.

4. **Would you be interested in a total redesign of the layout of a power bill?**

Yes No

5.2.2.3.4 Opinions of Conservation

The consumer's opinion on conservation plays a major role in helping us to determine how much energy he wastes, as well as what the major causes of the energy waste might be. This information will help us to determine solutions to the consumers' problems.

5.2.2.3.4.1 Energy Conscious Consumers

Finding out whether the consumer thinks that he is energy-conscious assists us in determining his opinion on energy conservation and also the amount of energy wasted. If the consumer doesn't believe that he is energy-conscious, then he probably isn't. However, just because he doesn't rate himself as energy-conscious does not mean that he doesn't care about energy conservation. This question is closed-ended with unordered responses. The consumer must evaluate each choice and select the one that best reflects his situation.

1. Would you rate yourself as energy conscious? Yes Somewhat No

5.2.2.3.4.2 Purchasing New Appliances

When buying an appliance, different appliances of the same type may use different amounts of electricity. For example, when comparing two different refrigerators, one may draw more amps than the other. Determining whether the consumer pays attention to this helps us gauge his electricity conservation. Educating the consumer about the differences of appliances may also help him to conserve energy. This question is closed-ended with yes or no response choices.

2. When purchasing new appliances, do you look at the energy consumption or conservation benefits of that appliance? Yes No

5.2.2.3.4.3 Conservation Programs

There are various conservation programs provided by Massachusetts Electric Company. These programs educate the consumer on how to use energy more efficiently, as well as on appropriate installation of insulation, water heating measures, light bulbs, lighting fixtures, and other items that aid in energy conservation in the consumer's home. Determining whether the respondents participate in these programs shows us how energy-conscious they are. The question on conservation programs is closed-ended with yes or no response choices.

3. **Have you taken advantage of offers from Mass Electric such as their 'Energy Wise' program and/or energy audits?** Yes No

5.2.2.3.4.4 Monitoring Appliances

By turning off appliances that aren't in use, consumers can save hundreds of dollars every year on their electric bill. Finding out if consumers shut off electrical devices that aren't in use is another way to determine if the consumer is energy-conscious. This is a closed-ended question with unordered response choices.

4. Do you turn off appliances to save electricity? (e.g., lights, radios, computers, or televisions when they aren't being used?) Yes Somewhat No

5.2.2.3.4.5 Insulation

Insulation is a key ingredient to big energy and dollar savings in the home. Federal Codes say that 6 inches of attic insulation is required. A homeowner who invests in the minimum 6 inches, spending between \$100 and \$200, will save about \$100 and \$200 the first year. But over the next ten heating seasons the savings will mount to between \$1,000 and \$2,000 (Derven and Nichols, 1976). Therefore, determining whether the respondent has proper insulation is important. Both of these questions are closed-ended. The first question, number 5, is a yes/no question, and a follow-up question, number 5b, is a closed-ended question with unordered responses.

5. Do you know if your house has proper insulation? Yes No
5b. If yes, is the insulation adequate or not? Yes it's adequate No it's not adequate

5.2.2.3.4.6 Electrical Device

An electrical device that gauged energy usage between electric bills would help the consumer become more aware of his usage in addition to helping him see if he is wasting a lot of electricity. Depending on the responses to this question, we will design this energy-gauging device, which will include a technical manual to assist the consumer. This final question is closed-ended with yes or no response choices.

6. **Would you be interested in a device that would provide feedback on electrical consumption between power bills, to help you gauge how much electricity you use?** Yes No

5.2.2.4 Order of the Questions

On part one of the survey, all the demographical questions are grouped together. The questions all have the same structure, being closed-ended with numerical response choices. The subjects of appliance information, opinions of bills, and opinions on conservation are all grouped together in parts two, three, and four. The parts also share the same structure, being closed-ended with unordered response choices.

The survey has a vertical flow, where the respondents generally move vertically down the page. Questions are also typed in boldface, and the answers are typed in normal print.

5.2.2.5 Design of Cover Letter

The first paragraph in the cover letter identifies the researchers and the school. The second paragraph informs the respondent of the background of the project as well as all of the parties involved. The next paragraph in the cover letter tells the respondent how and why he was selected for the study, and also the importance of his participation. The last part of the cover letter assures the respondent of confidentiality and thanks him for his assistance. These sections of the cover letter are business-like and professional and should increase the respondent's interest in our project.

5.2.2.6 Survey Type

After an evaluation of the literature and the options available to us given what the time frame dictated, we decided that the best option available to us was a mail-in survey distributed by hand. Of the different survey methods we had available to us, mail-in surveys, telephone surveys, and face-to-face interviews, telephone surveys were quickly eliminated. We had no way of determining the telephone numbers of the houses on a particular street without knowing some personal information about the owners of those houses. The Massachusetts Electric Company privacy concerns did not allow for this

Initially, we felt that a face-to-face survey of home owners would provide us with the most reliable data, but with the amount of time Massachusetts Electric Company left us to conduct our surveys (after they belatedly supplied us with their data—see below, Section 5.2.3), the possibility of face-to-face interviews began to fade. Both face-to-face interviews and mail-in surveys take time to prepare, but mail-in surveys take far less time to actually conduct than face-to-face interviews. The only drawback to mail-in surveys was the possibility of a low response rate, and the cost required for purchasing the stamps, envelopes, and making copies. Based on our time concerns, we decided a mail-in survey was our best option in this situation.

5.2.2.7 Packaging

The list of required items to include when sending the survey to a possible respondent consists of the following:

Addressed and stamped envelope
Copy of the survey
Copy of the cover letter

There were a number of possible additions to this list which we ruled out for cost or time concerns, most of which will be discussed later. Upon deciding what exactly should be sent to each survey recipient, we felt the best way to package the separate pieces was by using one envelope. The stamped addressed envelope was addressed to

Seth Chandler
WPI Box 1635
100 Institute Rd.
Worcester MA, 01609

And the return address on that envelope was:

Matt Clark

24 Lorna Dr.
Auburn MA, 01501

These envelopes, along with a copy of the cover letter and the survey, were folded into thirds and inserted into the outer envelope. The outer did contain an address and a return address, but we chose to leave off an actual postal address to avoid confusion with other types of mail. The address on the outer envelope was:

IQP Survey
The Conservation of Electricity
in a Residential Neighborhood

The information in the return address section of the envelope was:

Matt Clark
Worcester Polytechnic Institute
Mail ID Number ___:___

The design of the cover letter is mostly self-explanatory, and the purpose for the Mail ID number will be discussed in detail later. The outside envelope was closed (not sealed but the flap was folded closed) and placed in a box to await distribution.

5.2.2.8 Testing the Survey

Before the distribution of the surveys could take place, we took the time to do a trial run of 94 surveys to determine any possible problem areas the survey might have presented to the respondents, and to get a feel for analyzing the data which was returned. It is important to point out that the survey as discussed above is in revised form, and the revisions were made only after conducting this trial of our original survey.

The trial surveys were distributed in a neighborhood in Atlanta, GA, with only minor changes to the packaging, and a different cover letter which was better suited to the area surveyed. The surveys were submitted to every house in the neighborhood of one of the group members (Seth Chandler), and 69 of the 94 surveys were returned completed. The purpose of this section is merely to outline the changes which the test run precipitated; the full results of the trial survey are presented in the results section of this paper. The majority of the differences between the preliminary survey and the original, and why we chose to make those changes, are outlined in the paragraphs below. If the reader wishes to compare the surveys side by side, they are located in Appendices A.2 and A.4.

The first most obvious difference in the external packaging of the surveys was the way the envelopes were addressed. For the trial run, the external envelope was simply marked 'Lost Forest Neighbor' (Lost Forest is the name of the subdivision of Seth Chandler). The external envelope also had no return address. We decided to change this because we wanted the respondent to better understand what the envelope contained and why we were putting the envelope in his mail box. To remedy this, we added a return address, and changed the address field on the envelope to specify this was a survey for our IQP.

The second major difference between the test run of the survey and the final distribution was the address on the envelope we provided for the respondent to return his survey. The mailing address was the same, but the return address on the envelope was:

Seth Chandler
195 Mark Trail
Atlanta GA, 30328

The reason behind this was simple: the surveys were being distributed in Seth Chandler's neighborhood, and associating him closely with the survey was an easy way to obtain a higher response rate.

This same reason played a major role in the differences between the cover letter submitted with the preliminary survey and the cover letter submitted with the Auburn, MA survey. In the 'Lost Forest' preliminary survey, the cover letter was signed by Seth Chandler, because Seth was the project member the respondents would know. The cover letter in the Auburn survey was signed by Matt Clark, because likewise, Matt was the person the survey respondents would most likely know from our group.

Perhaps the biggest procedural change from the test run of the surveys to the final run distribution was the addition of Mail ID numbers. During the trial run of the survey, we were attempting to insure anonymity in hopes it would boost response rate, so all identifying marks were left off of the surveys. After subsequent thought on the matter, the Mail ID numbers were added for two reasons: to allow us to stratify the sample, and to allow us to determine who had responded to the survey and who had not, to aid with possible follow-up techniques.

Setting aside the procedural and packaging details, the majority of the differences between the test run of the survey and the final distribution of the survey were differences in survey layout and question design. The first difference between the two surveys that is immediately noticeable is the revision of the questions to bold face type. The reason behind this was to emphasize the questions in hopes of receiving more accurate responses. Another minor change made to the format of the survey was the inclusion of the Mail ID number field, and including our mailing address on the footer of each page of the survey.

The majority of the other changes made to the survey were related to question formatting. The first question on the survey, which may appear to be a simple question to answer, was the cause for some confusion among respondents. We assume that during the test run some of the respondents confused the age ranges with ranges of the number of people living in the house. While we expected to receive numbers in the response fields for this question, in some cases we received check marks or "X's" in the fields. To attempt to rectify this situation, we decided to place the qualifier "Ages:" in front of the age ranges, in hopes that in reading from left to right, the respondent would notice the keyword ages before marking a response. Again, if the reader wishes to examine the surveys, please refer to Appendices A.2 and A.4.

The second change that had to be made to the survey related more to the different geographic areas in which the surveys were tested rather than to any difficulty expressed by the respondents. The first question of the second section of the survey was modified to include oil heat as one of the power sources the respondents should ignore. The first survey was done in Atlanta, where virtually no one uses oil heat, whereas the second run was done in Massachusetts, where oil is a common power source for winter heat.

The next change to question format which was made due to the test run was including a response indicating no range or oven, or no electric range or oven. The original survey did not allow the respondent to indicate they did not own either of the appliances, and was the source of some confusion when the respondent attempted to indicate this.

The next change we made to the survey was less a result of the test run, and more a result of information obtained from the literature. In the test run of the survey we did not differentiate between refrigerators and freezers, a mistake which we decided to correct, as the appliances have very different energy usage.

The most significant problem indicated by the test run of the survey was the question involving pools and Jacuzzis. While the electric range and oven questions' lack of a negative response caused some problems, far fewer people own pools and Jacuzzis than electric ranges. We had virtually as many different responses to this question as we had respondents to the survey. Some people wrote in no, or N/A, or a no with a circle around it, but the point was we erred by not allowing them a way to respond indicating they owned neither of the appliances. This can be seen by examining question 7 in Appendix A.4.

There were far fewer changes that had to be made to the second page of the survey. The first change on the second page of the survey was to number the questions as we had done on the first page. Formatting inconsistencies from section to section are not a good idea when attempting to present a survey in a professional manner.

The second modification made on the second page was to change our newly numbered question four from a yes or no question to a closed-ended sorted response question. This allowed the respondent to indicate a middle position on turning off appliances to save electricity. A fair number of the respondents to the test run of the survey felt that there should be 'middle ground' on this question, and after evaluating the possibilities, we agreed.

The final modification on the survey was adding a follow-up question to question five in part four of the survey. The initial question asked the respondent whether or not he knew if he had proper insulation, and several respondents indicated that they knew, and in fact their insulation was not adequate. Though we do not strictly need to know whether or not the insulation in the house is adequate, the information could be used for a number of different purposes, including being factored into an analysis of the Massachusetts Electric Company data, or in recommendations for simple energy-saving measures.

All in all, the test run of the survey was extremely beneficial; a number of small difficulties which would otherwise not have been brought to our attention before the actual run of the survey were revealed. In addition, the data obtained in the test survey gave us some indication as to the way respondents might handle certain questions, and the interest in the work we have been doing in this project.

5.2.2.9 Distribution

After a thorough review of the literature, it was clear to us whatever method we chose to distribute our surveys had to be random or pseudorandom in nature. Another point that was extremely important to the validity of our data was to insure that the entire population was well represented, which is one of the reasons why random survey techniques are important in the first place. Our study population consists of single-family house dwellers, living on streets chosen by us, from a map in a discrete neighborhood in the town of Auburn, Massachusetts. The Massachusetts Electric Company data (which is covered in detail later) is from a random sample of all the houses on these streets. Therefore, we have decided to sample the same population as the Massachusetts Electric Company data, making two overlapping surveys.

Because of the Massachusetts Electric Company privacy concerns, it is impossible for us to know if a particular house on a particular street is contained in our data set or not. In fact, the only information we can be sure of is the number of houses contained in our population on a particular street. Because of this, we have decided to use stratified random sampling.

5.2.2.9.1 Sampling

The decision to use stratified random sampling was an easy one to make: the data we received from Massachusetts Electric Company was already divided up into streets, which we could use for our separate strata. Because we are sampling a population of unknown size, from which we already have a sample of 521, and we would like to have 95% significance at between a 5% and 10% confidence interval, somewhere between 96 and 384 surveys must be returned. From the literature, we gathered that a response rate of approximately 70% was possible when surveying adults with a professional survey. This would put the number of surveys we should distribute at approximately 300, assuming our target range for confidence intervals. Because we received 521 houses from Mass. Electric, we decided to stratify the houses by streets, and distribute as close to 300 surveys as possible, which turned out to be 298.

For purposes of comparison to the Mass. Electric sample, we decided to divide our sample into groups of similar size; our strata were approximately 60% of the number of houses in the Mass. Electric sample. After dividing the population into strata, and determining how many surveys should go to each particular street, the next task was to determine how exactly to distribute the surveys. In order to insure that our data is reliable, the surveys must be randomly distributed among members of each particular stratum. At first, one might think this is a complicated task, but in actuality, it is far from difficult. The argument is as follows: our population of 500 houses is divided up into a number of different streets. Each of these streets had a certain number of houses contained in the Massachusetts Electric Company data set, and our survey must be distributed randomly among 60% of that number of houses. Because each street on our list of streets contains a relatively small number of houses (i.e. less than 100), in both our sample and on the actual streets, it is safe to assume that the houses do not vary much over the length of the street.

For long streets which include a large number of houses, this assumption does not work. There may be apartments at one end of the street, and mansions at the other end. We feel however, that because of the small number of houses per street, that our assumption that the houses are self-similar is fair and safe. It is not likely that the houses on one side of the street use more electricity than the houses on the other side of the street, because we are assuming the households are for all intents and purposes very similar, and that by definition should allow us to assume the distribution is random.

Following this argument, if the distribution of the houses on each street is random, than distributing the letters to specific houses is simply not necessary. Rather than bring a calculator along and randomly generate addresses, we can rely on the fact that the houses in each neighborhood are similar enough to other houses in the same neighborhood, and give the surveys to any house we see fit. This may seem like an oversimplification of the process, but we assure you that if what we have assumed is true (and in all likelihood it is), this process is completely valid. We did not arrive at this decision lightly however. There were a number of random sampling techniques available to us for use in this project, but distribution of the letters in a sequential and or pseudo-random method seemed far more reliable in terms of determining where the envelopes were delivered, and far less time-consuming than traveling up and down a street with a calculator while randomly generating addresses.

5.2.2.9.2 Accounting of information

The reasoning behind including the Mail ID Number on the envelope is simple; we need to know which houses have responded to the surveys we gave them. The number is also included on the survey itself, as this is what we will be receiving back from the respondent. By noting the same identification number on both the envelope and the survey, we will be able to identify the surveys as we distribute them, and as we receive them back from the respondents. These numbers will be recorded when we distribute the surveys, and then 'crossed off' when we receive the surveys back. This way, we have a comprehensive record of who has completed the survey, but we maintain some form of anonymity, as the actual address isn't on the survey.

5.2.2.10 Analysis of Survey Data

The analysis of the survey data requires several different methods. The first section of the survey, the demographics section, is easily analyzed by averaging the data. The second section of the survey, much like the first section, can be analyzed using averages; it may also be analyzed in a way similar to the third and fourth sections of the survey, through counts of responses, and aggregate statistics on the data.

5.2.2.10.1 Analysis of Part 1

Through the use of descriptive statistics, much of the information in part 1 can be summarized effectively and efficiently. Some of the values to be computed are: the average number of people living in each household, the average number of men and women per household, the average age of people living in each household. All of these averages (and more if necessary) can be computed and presented with standard deviations. Visual representations such as bar graphs for age group breakdowns or pie charts for gender group breakdowns will contribute greatly to the overall presentation of this data.

5.2.2.10.2 Analysis of Part 2

The analysis of part 2 is an intermediary step in integrating the survey data with the Massachusetts Electric Company data. By evaluating the information received from the surveys, we can determine the percentage of people who own the appliances we asked about, and with that information we will be able to compute a rough average estimated usage number. The information in part 2 should be presented visually whenever possible.

5.2.2.10.3 Analysis or Part 3

The analysis of the information contained in the section pertaining to the electric bill is of particular interest to another goal in this project. Because of the simple scheme we have used in designing the questions throughout the survey, and in part 3 in particular, the representation of this data will not be particularly difficult. Much like the previous sections, the data can be represented visually to add impact to the presentation.

5.2.2.10.4 Analysis of Part 4

The analysis of Part 4 of our survey is similar to the analysis of part 3 in that one or more of our goals depends at least in part on questions asked in this section. Again, as with the previous three sections, it is extremely important to represent this data visually when possible. The other point of interest, touched on earlier, is that interest for the device we design for goal 3 of this project can be directly gauged by the response to the last question on the survey.

5.2.3 Massachusetts Electric Data

5.2.3.1 Introduction

The second half of the information required to determine the amount of electricity that people waste on average is monthly electric data for the same residential area surveyed. This data was obtained for us by David Falkowski, an engineer at Massachusetts Electric Company. We were put in contact with David by Paul Martin, who works with the MassMEP Company. Paul contacted people from the Massachusetts Electric Company, and they agreed to send us raw KWh data for 500 houses. Massachusetts Electric is very concerned with their customers' privacy, and they agreed to supply us with this data only under the condition that we would not require any personal information about customers, such as account numbers, phone numbers, addresses, or names. The other stipulation made by Massachusetts Electric Company was that the data they provided would not be for every house on a street, but rather a number of houses randomly selected from each street. This means the data is totally anonymous, and there is no way for us to tell which household supplied what set of data.

Because we wanted to survey all of the houses we got data from, we decided 500 houses would be a sufficiently large data set, and we agreed with his assessment. The information supplied by Massachusetts Electric Company is from flat-rate meter houses only. This means the houses are not operating on time-of-day pricing, but rather the rate is fixed, and does not depend on time of day or time of year. The other extremely important factor involved in selecting this data is ensuring that the data is only for single residence homes, rather than apartments, because that plays a large part in the amount of electricity used by each family (Parti and Parti, 1980). For all 500 houses, 12 months of kWh data will be supplied, allowing us to analyze both monthly and yearly statistics.

5.2.3.2 Details on the Massachusetts Electric Company Data

In order to better understand the scope of the Massachusetts Electric Company data, we have decided to outline the steps necessary to obtain the data, and the compromises we were required to make before we were allowed to receive that data.

When we first were put in contact with Massachusetts Electric Company, we asked for 500 single residence homes in the area of Worcester, MA. We left the location of the homes up to Massachusetts Electric Company, so long as they told us what streets the homes were on. We knew from the beginning we were probably not going to get the names or addresses associated with particular houses; this would have been beneficial in terms of the project, but was clearly contrary to some of the privacy agreements put on Massachusetts Electric Company by the State. The first set of data we received contained both single residence homes and apartments, and the bulk of the data (400+ houses) was from a single street in Worcester. Our project had focused on single residence homes in suburban areas. Thus, his was not the data we were looking for, because at this point the project was well under way, and it was not feasible to change the direction of the project to accommodate the data.

At this point, we decided to communicate directly with the Massachusetts Electric Company engineer, rather than through Paul Martin. The hopes were that we would be able to get data we could use, which matched the work we had already accomplished. After conversations with David, we determined an optimal solution to our problem was for us to survey a number of different streets, and allow Massachusetts Electric Company to pull random houses off each street. David felt that it might not be in their customers' best interests to give out all the data on a particular street, because then we would know we had data from every house. They felt that if we did not know for certain for which houses we had data, it would be less likely to be viewed as an invasion of privacy. The following is the list of streets we provided to David:

```
Lorna Dr.
Burnett St.
Horseshoe Dr.
Laurel St.
Zabelle Ave.
Green St.
Berlin St.
Rockland Rd.
William St.
Arrowhead Ave.
Walnut St.
Burnap St.
Inwood Rd.
```

Each of these streets is located in Auburn MA, and we made sure to specify that when talking with David. We arrived at these streets by selecting an area of Auburn, MA, and using a map to select streets proximate to that area. When we received the data, there appeared to be some irregularities in the number of houses on each street. When we asked David to specify how many houses were on each street, we were sure that the data had been pulled from the wrong are of Massachusetts.

After another round of conversations with David, we determined that the anomalies in the numbers of houses on particular streets were due to the fact that when the information was pulled, they forgot to specify to only pull houses from Auburn, MA, for the particular streets. As it turned out, a number of the street names we specified were found in more than one area in Massachusetts. When we ironed out these difficulties, David suggested we give him a new list of streets, and this is the list we presented to him:

```
Lorna Dr.
Burnett St.
Horseshoe Dr.
Zabelle Ave.
Rockland Rd.
Arrowhead Ave.
Burnap St.
Inwood Rd.
Old Cart Rd.
Briarcliff Dr.
Ashcroft St.
Wallace Ave.
Bylund Ave.
Wallace Ter.
Pinebrook Ct.
Vinal St.
Nancy Dr.
Oakwood Ave.
Rockland Rd.
Rockland Rd. Ct.
Idlewood Dr.
Homestead Ave.
Berlin St.
```

After sending this list to David, he was able to give us data for 521 houses in Auburn, on the streets provided by us. The same procedure for selecting these streets was used as above, though we made sure to specify more streets in order to receive the amount of data we were looking for. The only difference was that due to naming constraints, Wallace Ave. and Wallace Terrace were aggregated under the same name; this is also the case for Rockland Rd. and Rockland Rd. Ct.

5.2.3.3 Details on the Data Format

Before determining how to analyze the data from Massachusetts Electric Company, it is important to examine the details of exactly what the data contained, and how exactly it was formatted. The data was separated by houses and months, and the different pieces of information were separated out into columns. Each line contains the following: a number (between 1 and 500), which corresponded to a particular house in the data set; the name of the street on which the house is located; the beginning date for the billing period; the ending date for the billing period; the billing code (always R1A for our data); the actual kWh usage information for that month; and whether or not the bill was actual or estimated. For example, the data for a particular house might appear as follows:

```
00001 BURNETT          20010216 20010320 R1A 000000380 E
00001 BURNETT          20010320 20010420 R1A 000000295 A
00001 BURNETT          20010420 20010517 R1A 000000233 A
00001 BURNETT          20010517 20010618 R1A 000000289 A
00001 BURNETT          20010618 20010718 R1A 000000322 A
00001 BURNETT          20010718 20010816 R1A 000000360 E
00001 BURNETT          20010816 20010917 R1A 000000398 A
00001 BURNETT          20010917 20011017 R1A 000000265 A
00001 BURNETT          20011017 20011116 R1A 000000276 E
00001 BURNETT          20011116 20011218 R1A 000000324 E
00001 BURNETT          20011218 20020124 R1A 000000352 A
00001 BURNETT          20020124 20020225 R1A 000000277 A
```

The first number `00001` indicates that this is the first house from the entire data set. The second field, `BURNETT`, indicates the street on which the house is located. The rest of the information indicates the usage by the customer and for what month. The first line would mean this particular customer is estimated to have used 380 kWh of electricity from February 16, 2001 to March 20, 2001.

5.2.3.4 Use data to calculate descriptive statistics

The first thing to do with the data from Massachusetts Electric Company is to calculate descriptive statistics on the information. Descriptive statistics, a rather broad term, include information such as mean, median, standard deviation. In order to obtain averages we can use, several things must be taken into account. First and foremost, the length of the billing periods must be calculated for every month for every house. Using the length of the billing periods for every house, we are able to determine the average daily usage for a house per given month. More useful than this however, is determining the average yearly usage, as this is how we will be correlating the Massachusetts Electric Company data with our survey data. In order to do this, the kWh usage provided in the data is summed for each individual house. Then, the length of the billing period is summed, and the kWh usage is divided by the number of billing days. This gives us the average daily usage for the entire billing year. To scale this to a reasonable metric, we then multiply back by 365 to give the average yearly usage for that particular home in a non leap year. Using this data for each house we are able to calculate meaningful descriptive statistics on yearly usage, and this information is in turn available to us for use in correlating our survey data with the Massachusetts Electric Company data.

5.2.3.5 Correlating Electric Company Data with Survey Part 2 Results

The correlation of the data obtained from the Massachusetts Electric Company information and the survey results are at the heart of our project. The results provided by these calculations will provide rough estimates of how much electricity should be used by particular households, and how much electricity is actually used by particular households. The difference between these two values is a measure of how much electricity is wasted by a particular household. The amount of electricity used by a particular household is the sum of the energy used by the appliances in that household. After the appliance ownership information is obtained, average usage information can be used to estimate how much energy the average household will use in a given period of time. This figure can then be compared to the actual electricity usage provided by the Massachusetts Electric Company data.

5.2.3.5.1 Obtain appliance information

It is necessary to determine the average usage information for the specific appliances we asked about in our survey. Most of this information is readily available on the internet and through various other sources (See Section 4.1.5 Appliance Specific Information, p. 26 and ff. in this paper). By determining first the average range of annual usage, and then identifying a figure to use for our particular calculation, we will be able to determine the average yearly usage for specific appliances for the homes that we surveyed.

5.2.3.5.2 Determine average yearly usage for the houses

There are three parts involved in computing average yearly usage per home; the first is determining the average number of the specific appliances we asked about in the survey per house. This is a fairly simple proposition; simply dividing the number of people who own that appliance by the total number of respondents gives us the average number of appliances per home. The second step in determining yearly usage is then multiplying the appliance usage information times the stock of the appliance (the number of those appliances per home). This gives us the average amount of electricity that appliance will use per home per annum. The final step in the process is simply summing the values obtained for each appliance, to determine the total yearly average.

<u>5.2.3.5.3 Compare the two figures obtained</u>

Finally, armed with both the averages computed from the survey data and the averages from the Massachusetts Electric Company data, we are able to determine the amount of electricity wasted on average. The Massachusetts Electric Company data minus the survey average gives us a rough solution to what has been and still is an incredibly difficult problem to solve.

5.3 Goal 2: Help consumers to understand their power bills

5.3.1 Introduction

If in fact our results indicate that consumers generally do not understand their power bills, it is important that we are able to determine where consumers have difficulty with their bill. Because our preliminary results indicate that consumers indeed have difficulty understanding their electric bills, we have decided to design a usability test on the electric bill.

5.3.2 Purpose

The purpose of this usability study is to find and fix the flaws in the Mass. Electric monthly power bill. More specifically we are looking for where the consumer may be having trouble interpreting the bill and how it could be changed to be more user friendly, so the consumer can actually see what most of the numbers mean.

5.3.3 Objectives

The objective of this test is to find some difficulties in the Massachusetts Electric Company's Power bill, by using about seven users that currently pay or will have to pay electric, and therefore should have a reasonable understanding of what it is that is displayed on the power bill. He or she should have a solid grasp of some key areas to be defined later in this report and be able to execute brief tasks that demonstrate this knowledge. From their answers to these questions we will determine where the obstacles are that prevent completion of these simple tasks (Rubin 1994). We will be timing their answers and noting any hesitancy towards answering a question or locating a key item that is on the bill. From this part we will be able to see if our product (the power bill) has any usability flaws which would prevent or impede the user (the bill payer) from completing his task, which is understanding the numbers on the power bill, seeing if he is using more power than this time last year, paying the correct balance due and thinking of ways to conserve electricity. If a second test is to be completed, we need to make sure that the new product (the newly redesigned power bill by our group) has less usability flaws than the old one. The last thing that we need to make sure of in the test is that with the new bill there is an appropriate balance of ease of use and ease of learning. What this means is that the bill should be easy to read, but also easy to learn for new customers (Rubin 1994).

5.3.4 User profile/target audience

The target audience for this study is going to be anyone that pays or will have to pay a power bill in the future. This audience is going to consist of a population of around eight people. We will be testing a variety of college students and professors, and the reasoning behind this is that everyone at some point in his life is going to have to deal with an electric bill of some sort, and should know how to read it. In this case, race, age, and gender do not matter. Obviously we cannot test three year olds, but college students are fine because some are paying electric bills right now, and the others will have to at some point in their lives. It has actually been proven that as little as four users can show you more than 80% of the usability flaws that are in the product (Rubin 1994).

5.3.5 Design

The design for our usability study is fairly simple due to the short overall length of the Massachusetts Electric bill. In the task list section, we define a number of questions to ask the test subject. Basically speaking, we ask the user to perform specific tasks, and record their actions and responses for later analysis. It is important that all the tests are consistent, and that we pay attention to any small mistakes the user might make during the course of the test. In addition, it is also crucial that we pre-test the usability test, to point out any bugs or flaws in our design. The final requirement of the test design is that in discount usability engineering, the subject has to be comfortable in the testing environment.

5.3.6 Task list

Simply stated, the task list is to find the flaws within the design of the Massachusetts Electric Company bill. Materials will be the bill, and possibly a voice recorder. How will we know if our test is successful? The only real measure of this is going to be to see our newly designed bill and how users respond to it. In the actual test, our questions need to be prioritized by frequency. This means that the first question that is going to be asked is going to be the one that is executed by the user most often (locating the balance due). It just so happens that in our test this is also the most critical task. Most of our tasks were given in the above Method section. What we are trying to do is ask questions about what charges users have control over, and to show them (or at least just make them aware) that other charges do apply, and that the amount of these charges does not depend on how much electricity you use in the month—you are going to pay for them no matter what happens. When giving the test, we will have some reasonable times written down that we will be using as a benchmark for the test. We will be recording how long it takes each user to do these tasks and making sure that they point to the correct value. The test will begin with the following pre-test question: Do you pay a power bill currently? This question should be closed-ended (yes or no) so that the subject is not confused or intimidated before the test starts (Rubin 1994).

5.3.6.1 Question 1

Please locate the amount that you now owe the electric company (this month and any other back charges). – This question is asked first because we need to prioritize by frequency, which as explained before needs to be done because this should be the first and foremost task for the typical user of the Mass. Electric bill.

5.3.6.2 Question 2

Please locate the due date of this charge. – Again this question is positioned because of prioritizing by frequency and importance. The next logical thing for the user to do after locating his final balance is to see when his check or payment has to be submitted by to avoid late charges or possible termination of service, which would be very detrimental to his credit rating.

5.3.6.3 Question 3

Is this bill estimated or actual? – This is often overlooked by the users. Sometimes the electric company will estimate what your bill should be for a billing period, based on your power usage for the same period during the preceding year. If it is an actual bill, this means that a meter man came to your place of residence and actually read the meter, and that is what you are being billed for.

5.3.6.4 Question 4

How many KWH did you use for this billing period last year? – The reason for asking this is to see if the subject knows if he has increased or decreased his power usage in the past year. There are many factors that could contribute to an increase or decrease in power usage, such as a colder winter, or possibly the introduction of a new member of the household. The results of this question can be used in other aspects of our project to pinpoint if people are cutting down electricity usage or increasing it, and most importantly what factors contribute to this.

5.3.6.5 Question 5

What month did you use the most KWH last year? – This is a transition question to reassure the subject that this is not a hard test. This needs to be done at least once in the study (Rubin 1994). Again here we will be able to see if the subject knows how to read the past portion of the bill, and we can use this information in other parts of our project to possibly see in what months consumers are drawing the most power.

5.3.6.6 Question 6

Locate the dollar amount that you are charged for "energy conservation" – We are asking this because we want to see how many people actually know that everyone is being charged money to start energy-saving programs like light trade-ins.

5.3.6.7 Question 7

Locate the dollar amount that you are charged as a flat rate (you have no control over this charge) – This is another question designed to see if people know that they are being charged a flat rate no matter how much electricity they use.

5.3.6.8 Question 8

Locate the amount of money that was paid by you last month, and what amount is currently overdue on the bill. – These are tasks that the user should be familiar with so that he can know how much was indeed paid last month and what the carrying balance was over to this month. These are again general tasks that should be fairly easy to perform and allow us to see if the users can find these items easily.

5.3.6.9 Question 9

Is this bill standard offer or default service? Do you know what the difference is? – This question is a tough one because neither of these two topics is described on the bill, but the bill does say what type of offer you are using. The difference here is that if the user chooses standard offer, then he is getting his electricity straight from Mass. Electric, rather than through a reseller. Default service is when your service defaults back to Mass. Electric, if you decide not to use a reseller you had been using previously, or have not yet picked which company to use.

The post test question will be open-ended, because now the subject has completed the test and will be familiar with our purpose in this study, so they will be able to give us a detailed answer to the following: Where do you think you had the most trouble on the test and where do you find points on the bill to be the most ambiguous?

5.3.7 Environment

The environment where the test is administered should be some place familiar to the subject. This is a 'discount usability test', so it is not going to take place in a square room with white paint and make the person feel isolated. It should be a place where the user would typically be viewing the bill. Going into a user's home is generally not possible, so we will try to do this in the most comfortable room or area possible within reason. This is important because the user should not have to feel like he is part of a lab test, but rather an informal examination of the Mass. Electric bill. The environment in which a usability study takes place often plays a large role in making the user feel intimidated or at ease at the beginning of the study. We have attempted to keep this in mind, because a nervous subject does not always render the best results. With this in mind, we should get the results that we will need to redesign the bill.

5.3.8 The role of the monitor

Generally, the role of the monitor is to pay close attention to how the subject reacts, and to give him some assistance if need be, but to make sure that we note that he needed some help. After recording his reactions and answers, we need to formulate on a person-to-person basis what this means in regards to how the bill should be changed. Our biggest task is to make sure that we are consistent with how much help we give the subject and to not favor anyone. This will ensure the ideal results. Here we want to make sure that we do not lead the user to an answer towards the end of the quiz. Two factors that could cause this are the tone in which we ask the questions, and the questions that we actually ask (and their order) (Rubin 1994). Leading the user to certain answers will totally skew our results, and could jeopardize the results of the entire usability study.

5.3.9 Measures of evaluation

Different performance measures are available in analyzing and evaluating a subject during usability testing. Areas that need to be keyed in on are whether the user can complete the tasks, how long it takes for the user to complete each task, and the number of tasks completed in X amount of time. Other performance measures which may apply in this situation are the subject's reactions to our questions, and to the pre and post test questions. In addition, it is important to note the number of negative comments about the bill, or difficulties the subject expressed verbally with our test.

5.4 Goal 3: Help consumers conserve electricity and save money

5.4.1 Introduction

Apart from the help consumers might receive from a better understanding of their power bills, we have decided on an intriguing option to allow consumers to gauge their own usage of electricity independent of the electric company. While consumers have always been able to read their own electric meters, the amount of information provided to the consumer is extremely limited, and the burden of determining their electric usage is placed entirely on the consumer.

Our proposition then, is to design a device which would allow the consumer to easily gauge his energy usage independent of the electric company's facilities. This device should be as easy to use as possible, but also provide a detailed analysis of the energy usage of that particular home. There are two parts to the design of this particular device. First, the requirements for the device must be determined, and second, the actual interface for the device must be laid out and then analyzed with respect to certain performance metrics.

The majority of the work done in this section is based on personal experience with interface design, and skills learned in Human Computer Interaction. While the design of interfaces for interaction between human and machine is somewhere between a science and an art, there are well-established practices which somewhat ease both the scientific and artistic burden on the creator of that interface. We have attempted to follow these guidelines wherever possible in the design of this device.

5.4.2 Device Requirements

The first step in designing a device to help consumers understand their consumption of electricity is determining what the device should be able to do, based on the requirements. The basic requirements of the device are to measure usage, store the measurements, and display the measurements in different ways to the user. After the specific requirements have been determined, we can begin the bulk of the work in designing the specifics of the device.

5.4.2.1 Measure Usage

The first major requirement that the device must satisfy is the measuring of information on the amount of electricity used. One of the ways to do this is to integrate current over time; by doing this one will end up with the kWh reading for the household. This particular method has several distinct features: it allows us to read the draw by the house at the time, and it allows for estimation of the total amount of electricity used.

5.4.2.2 Store Usage Information

In order to allow the consumer to effectively use this device, it must not only measure usage, but store usage for a specific amount of time. The amount of memory required to store incremental usage readings varies based on the number of readings that must be stored. There are several different schemes available to us in deciding how much information the device should store. Some of the methods are storage with constant increments, or storage with reverse chronologically increasing increments.

5.4.2.3 Display information back to the user

Perhaps the most important requirement of the device is displaying the information collected from the electric panel, the circuit box, and then stored in the device. This may seem like a relatively easy task at first, but much more thought must be put into interface design than an inexperienced engineer knows. It is no accident that companies spend thousands upon thousands of dollars researching effective user interfaces for their software, or that there are literally numerous studies done on usability of websites. No matter how soundly a product is engineered, if it is not usable by the target audience, the device will never obtain widespread use. This device is no exception; we must give it a design that follows sound interface design principles while still adhering to the device requirements. Therefore, the on-screen interface as well as the physical interface will be designed keeping a number of interface design considerations in mind.

5.4.3 Design Device

As mentioned previously the design of the device and the interface for the device are as crucial to the adoption of the device as the idea behind the device. There are several different facets to designing the device; the majority of this section will be focused more on the actual interface the consumer will be working with. The other parts to device design will be covered in section 5.4.4, which will mainly focus on the physical implementation of the design.

5.4.3.1 Sketch of Interface

The first step in designing the actual device is to provide a sketch for the physical user interface. This is simply a rough picture for the way the device will physically appear to the user. The sketch should include the size of the device, the size of the screen, and the layout of the buttons the user will use to interact with the device. Again, this is not a technical diagram of the device, but is rather intended to give people an indication of how the device will look.

5.4.3.2 Internal Interface Design

A technique widely employed by software developers in interface design is the use of storyboard, a technique which we will borrow for this particular phase of design. Storyboards are basically a 'snapshot' of the user interface at a particular point. Before storyboards can be constructed however, the menu design and screen layout have to be determined; then storyboards can be used to show a flow through the menu tree.

5.4.3.2.1 Menu Design

The menu design for this particular device is a fairly simple endeavor. First and foremost, the menu structure must be simple, and easy to navigate. These two requirements lend themselves quite nicely to tree structured menus. The depth and the breadth of tree structures depend on several things: the number of commands that must be displayed in the menu tree, and the hrair limit. In order to facilitate design, the menu design will be shown in this paper as a tree structure.

The hrair limit is a so called 'magic number' in interface design and cognitive processing. Basically stated, humans can only process a maximum of seven plus or minus two items at a time. The pioneering work done in this field was done by George A. Miller, in his 1956 paper 'The Magical Number Seven, Plus or Minus Two: Some Limits On Our Capacity for Processing Information.' Needless to say, the title of his paper speaks volumes on the matter. The term hrair was actually coined by Grady Booch when referring to the 'magic number', who borrowed the phrase from Watership Down, by Richard Adams.

5.4.3.2.2 Button Layout

The layout for the buttons on the physical device may at first seem unimportant, but in interface design, almost everything has a reason behind it. Generally speaking, the layout for the buttons on this device will follow the interface guidelines for placement of buttons on toolbars and the location of certain features on screen for computer programs. Everything is placed in order to minimize distance, and the same should be true for our design. One would not want to be 'jumping all over the place' to get a few simple commands entered into our device. In addition, we are trying to make the design fairly simple and our objective would be more easily accomplished if the layout of buttons were simple enough to facilitate a fast learning curve.

5.4.3.2.3 Screen design

The design of the layout for the on-screen display is based on several different things. First of all, the menu structure we develop will play a big part in the way the screen is structured. Finding an effective method to display menus while still maintaining some sort of cleanliness in the interface should be one of our priorities. Our number one priority in designing the screen, however, is to ensure that the design is uniform for all screens, to ease the initial learning and to allow people to make expectations based on previous experience.

5.4.3.3 Interface usability analysis

There are some relatively simple ways to gauge the efficiency of an interface design, without incurring huge time costs. One such gauge is to use certain artificial metrics called performance measures to determine how complicated an interface is. This might be something like how many buttons need to be pressed in order to accomplish a certain task. Another of the techniques we will be using is a more specialized form of performance metrics, by simply going over the menu structure to determine its efficiency.

5.4.5 Calculation of costs

One of the important requirements in designing a device to help consumers gauge their energy consumption is to determine the amount of money a device like this would cost to build and install. While it may be difficult for us to determine the cost of the device, we are able to estimate the amount of time and money required to install the device, as well as the cost of some of the major components for the device.

6 Results

6.1 Introduction

The results of the work we have done to accomplish our goals are best broken down by the goals which they support. As was done in the methodology section, the survey results and the Massachusetts Electric Company results will be presented under Goal 1, the usability study's results will be presented under Goal 2, and some simple performance metrics for our device will be presented under Goal 3.

6.2 Goal 1 – Survey and Massachusetts Electric Company Data

6.2.1 Survey Results for Pre-Test

While the results for the Auburn survey are pivotal to the outcome of this project, the results of the survey pre-test, done in a suburban area in Atlanta, GA, are of less importance. Therefore, the presentation of the results of the Lost Forest neighborhood survey will be much less in-depth than that of the Auburn survey. The answers to parts one, three, and four are still somewhat applicable to our project, but the responses to part two of the survey are not applicable to this project other than to point out where faults were in our survey design, so they will not be presented here.

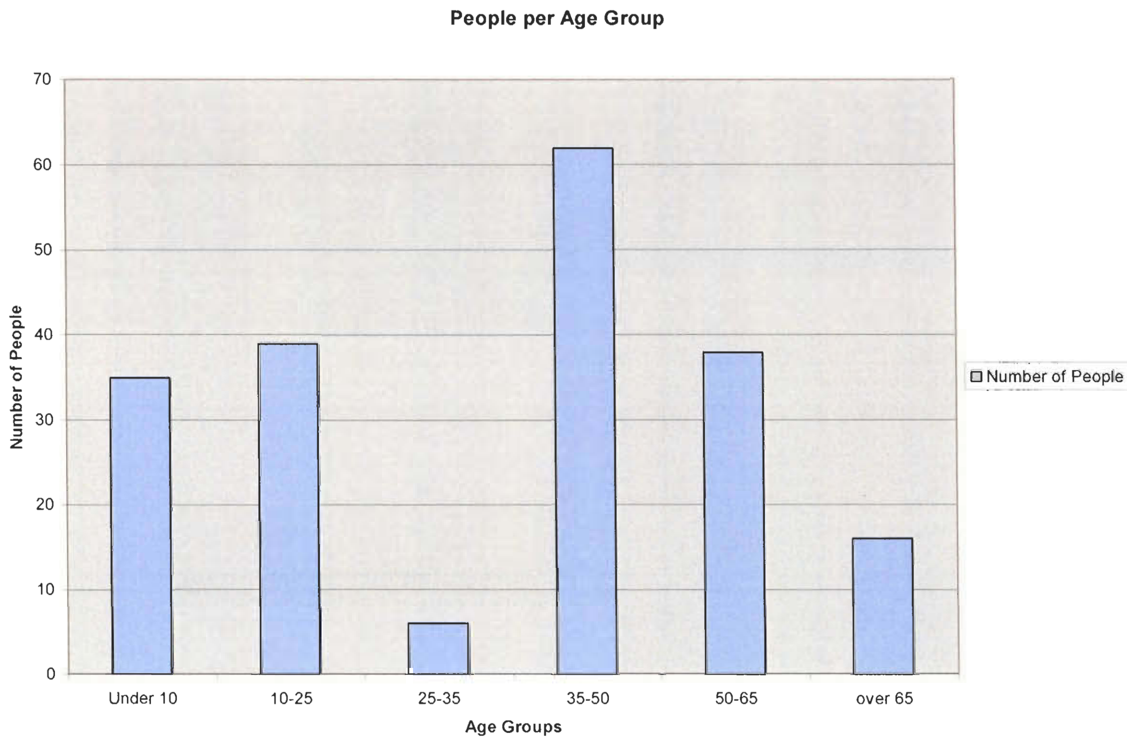


Figure 6.1 Age Groups from Pretest

In Figure 6.1, the results for the question we asked of the pretest respondents on age are presented. The age groups in this section are quite similar those presented in the following section, indicating only a slightly different demographic makeup than that of the Auburn survey respondents.

The gender breakdown of the pretest responses is represented in figure 6.2. Out of the 206 people indicated in this question, 109 were male, and 97 were female. That meant that our target population was approximately 53% male. As mentioned above, the results for part 2 of the survey have been omitted, because they are not applicable to our Massachusetts Electric Company data. The number of people in each house ended up at approximately 3.03 people per home.

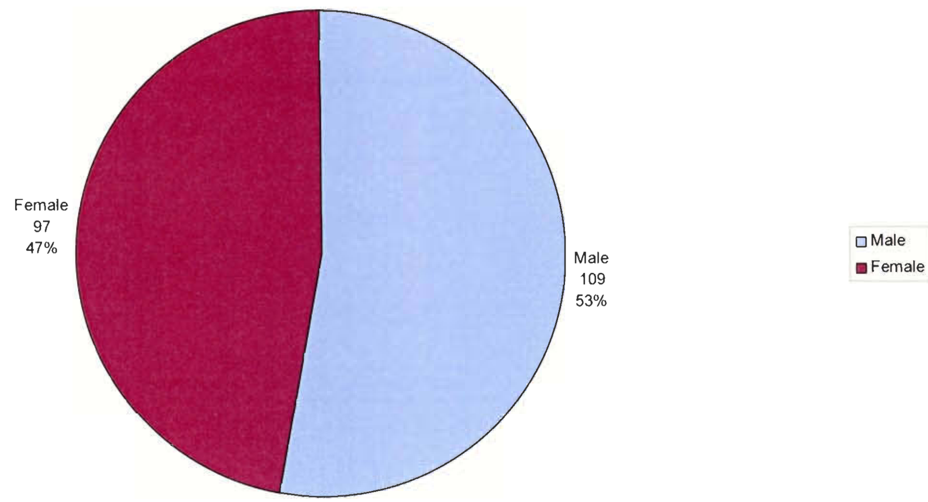
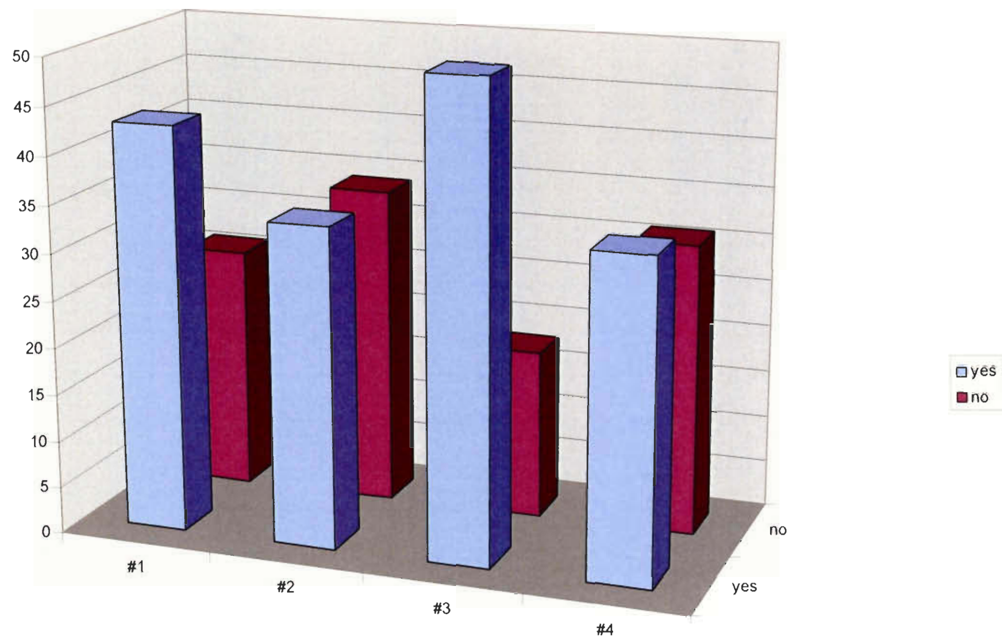


Figure 6.2 Male and Female Respondents for Pretest

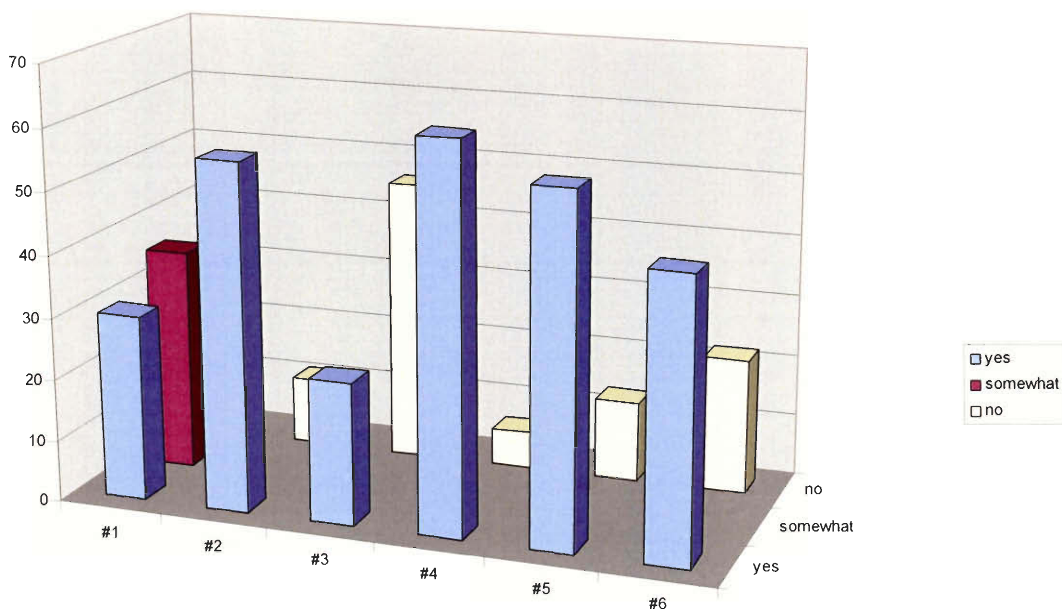
As the format for part three of the survey remained largely the same between the pretest and the post test, the results for part three are still applicable to our project. We have presented these results in summary form in figure 6.3. 43 out of the 69 respondents knew whether their last electric bill was estimated or read. There was an even split between respondents on the question of whether or not they felt they understood their electric bills. On the final two questions of part three, there was overwhelming support for a guide to the electric bill, and though the numbers were closer, the majority of the respondents felt that they could benefit from a redesign for the power bill.



	#1	#2	#3	#4
yes	43	34	50	34
no	26	34	18	31

Figure 6.3 Responses to Part 3 for Pretest

The final section of the survey, which we modified in part between the pretest and the actual survey, is also still applicable to the results of our project, and is presented in figure 6.4. There was an almost even split in the first question, with most of the respondents identifying themselves as energy conscious or somewhat energy conscious. The results for the second question indicate that respondents overwhelmingly look to government standards like energy star rating when purchasing appliances. The results for the third question revealed the fact that the majority of respondents to this pretest in fact had not taken offers similar to the 'Energy Wise' program offered by Massachusetts Electric Company (called 'Good Cents' by Georgia Power). The results for the fourth question were by far the most one-sided of this section, indicating that 91% of the respondents turned off appliances to conserve electricity. Similarly one-sided results were obtained in the fifth question on part four, when we asked the respondents to indicate whether or not they knew if their home was properly insulated. Finally, the last question on the survey asked customers whether they would be interested in a device designed to help them gauge electricity between electric bills, and the response was exceedingly positive.



	#1	#2	#3	#4	#5	#6
yes	30	56	23	62	56	45
somewhat	36					
no	3	11	46	6	13	22

Figure 6.4 Pretest Part 4 Results

6.2.2 Survey Results for Auburn Survey

The results presented below for the survey we distributed in Auburn, Massachusetts, are based on the 133 separate responses we received in the weeks following the distribution of the survey. Based on an unknown population size, our distribution of 298 surveys, and the return of those 133 surveys, we can determine several key numbers for our analysis. First, the responses by 133 of the 298 surveys we distributed gives us a response rate of 44.6%. While this response rate is less than the 60% we had hoped for and anticipated, it gives us a reasonable range for error.

With an unknown population, and 133 returned surveys, our confidence interval is 8.5 with a 95% confidence level, and 11.19 with a 99% confidence level. While a range of ±8.5 and ±11.19 for 95% and 99% confidence levels respectively are not the ±5 that we had hoped for, they are still reasonable bounds on the accuracy of our data. The sample population for the Massachusetts Electric Company data and our survey should overlap considerably, but because of Massachusetts Electric's privacy concerns, we are unable to determine to what degree this overlap existed.

6.2.2.1 Survey Part 1 Results

The results presented in part 1 of the survey give us an appropriate background of the households in our target area. The first question in part 1 of the survey asks how many people live in the house from each of the age groups provided. A total of 374 people live in the 133 houses being analyzed, for an average of 2.9 persons per house, with a range of 7, from 1 to 8 people (see Table 6.1). Of that 374 people, 11.5 % were in the under 10 age group, 23.3 % were aged 10-25, 10.7 % were in the age group 25-35, 23.0 % were in the 35-50 age group, 17.6 % were in the age group 50-65, and 13.9 % of the people in the households were over 65 (see Figure 6.5).

Table 6.1 Total People per Home for Auburn, MA survey

Total People Per Home

Mean	2.9
Median	3
Mode	2
Standard Deviation	1.424318
Range	7
Minimum	1
Maximum	8
Sum	377
Count	130

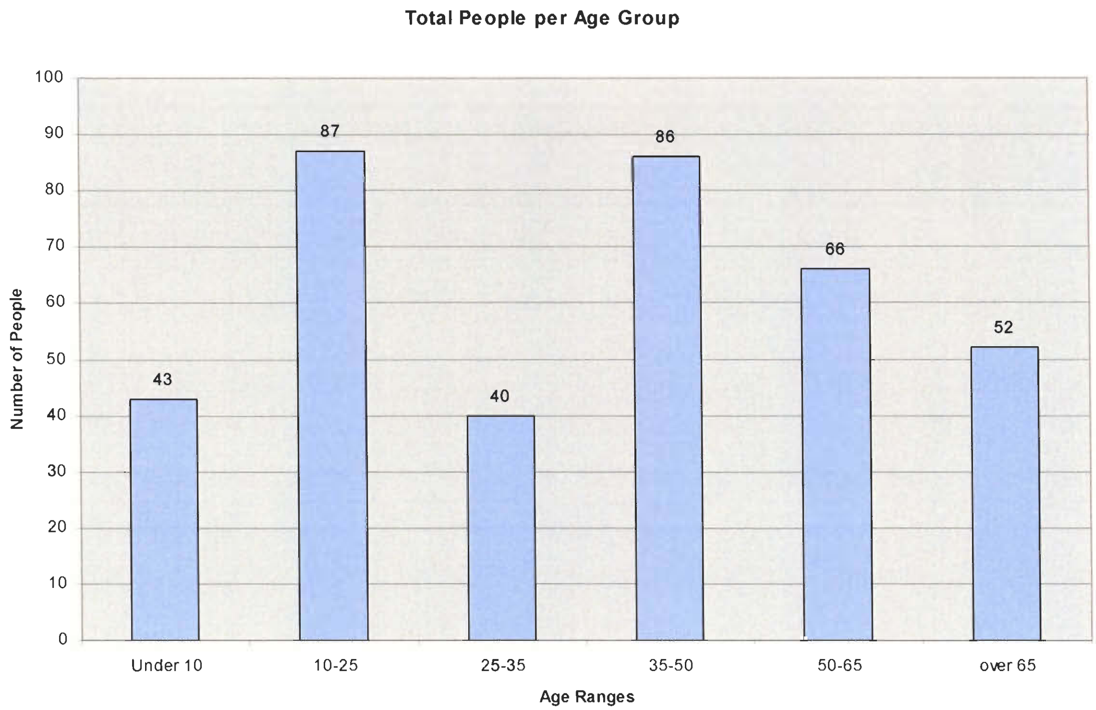


Figure 6.5 Age Groups for Auburn Survey

The trends in the distribution of age groups are quite simple. Individuals in the 25-35 year age group are likely to have children in the under 10 age group. That is the reason why the total number of individuals in each of those categories is almost identical. Individuals in the 35-50 age group are likely to have children in the 10-25 age group.

This theory is supported by our results; the total number of individuals in those two age groups are approximately equivalent. The 'Count' row in Table 6.2 indicates the number of houses with people in these particular age groups. 'Mean' indicates the number of people in that age group per home, assuming that home had people of that group (in other words, in houses with people 'Under 10,' there were 1.59 people on average in that age group).

Table 6.2 Age Group Descriptive Statistics

	Under 10	*10-25*	*25-35*	*35-50*	*50-65*	*over 65*
Mean	1.5925926	1.7058824	1.6	1.5925926	1.4347826	1.4444444
Median	2	1	2	2	1	1
Mode	1	1	2	2	1	1
Standard Deviation	0.6360491	1.0824808	0.5	0.4959656	0.5012063	0.5039526
Range	2	5	1	1	1	1
Minimum	1	1	1	1	1	1
Maximum	3	6	2	2	2	2
Sum	43	87	40	86	66	52
Count	27	51	25	54	46	36

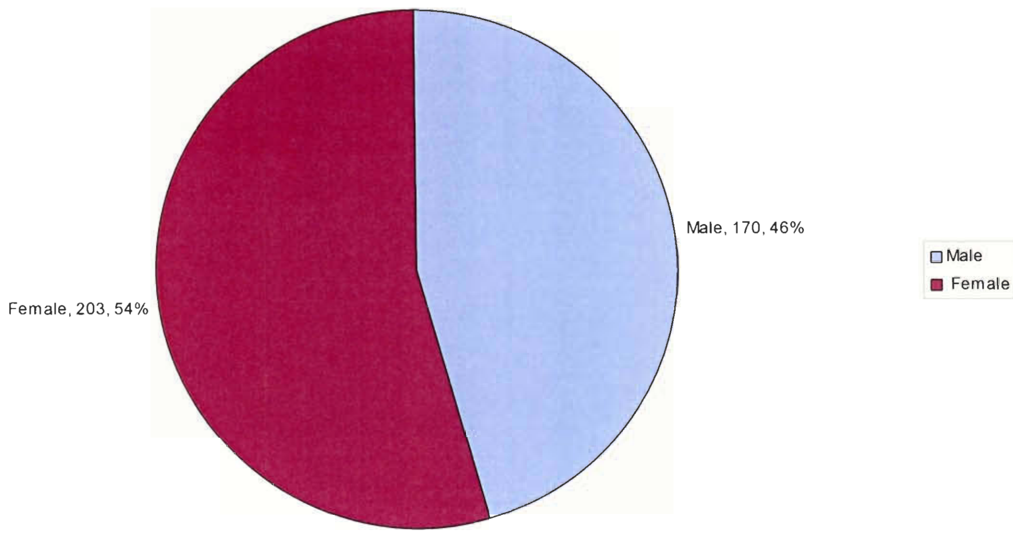


Figure 6.6 Gender for Auburn Survey

The second question in part 1 of the survey simply asks for the number of people from each gender living in the household. From the returned surveys, a total of 373 people live in the houses. This total should theoretically be the same as the total in question 1, but because of respondent error, the total in question 2 is missing one person. Of the 373 total individuals, 203 (54%) were of the female gender. One hundred seventy males, or 46%, lived in the households. Thus there are nearly an equal number of male and female individuals, with females being slightly more numerous (see Figure 6.6).

Table 6.3 Years in home for Auburn Survey

	Years in House
Mean	20.46712121
Median	18
Mode	4

Standard Deviation	16.13934856
Range	69.5
Minimum	0.5
Maximum	70
Sum	2701.66
Count	132

The third and final question of part 1 of the Auburn survey inquires how long the respondents have lived at their residences. From the returned questionnaires, the average length of time respondents lived in their houses was 20.47 years (see Table 6.3). The minimum length of time in the house was 0.5 years, and the maximum length of time was 70 years.

6.2.2.2 Survey Part 2 Results

The results of part 2 of our survey are quite unlike the results for any of the other parts of the survey because they must be correlated with the Massachusetts Electric Company data discussed below. In order to correlate the two different sources of data, we must use averages, so this data will be presented in terms of aggregate statistics and some descriptive statistics, ordered by question numbers. Finally, due to the varied questions asked in this part of our survey, we are unable to present the data in a more condensed fashion. We felt that in light of this, pie graphs and charts were the best way to visually represent our data.

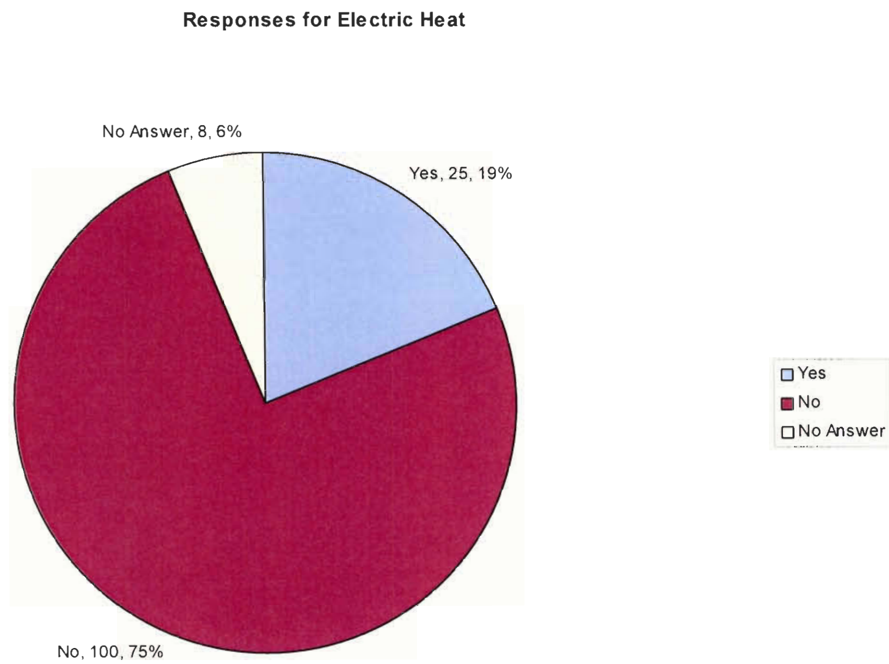


Figure 6.7 Ownership of Electric Heat among Respondents

The first question we asked in Part 2 of our survey was whether or not the respondents owned any electric heaters for their home. As seen in Figure 6.7, the majority of the respondents did not have any form of electric heat. Out of the 133 responses, eight people did not indicate whether or not they had electric heat, 25 people indicated they had some form of electric heat, and 100 subjects indicated they had no form of electric heat. In other words, for purposes of correlating the data, there are approximately 0.2 electric heaters per household.

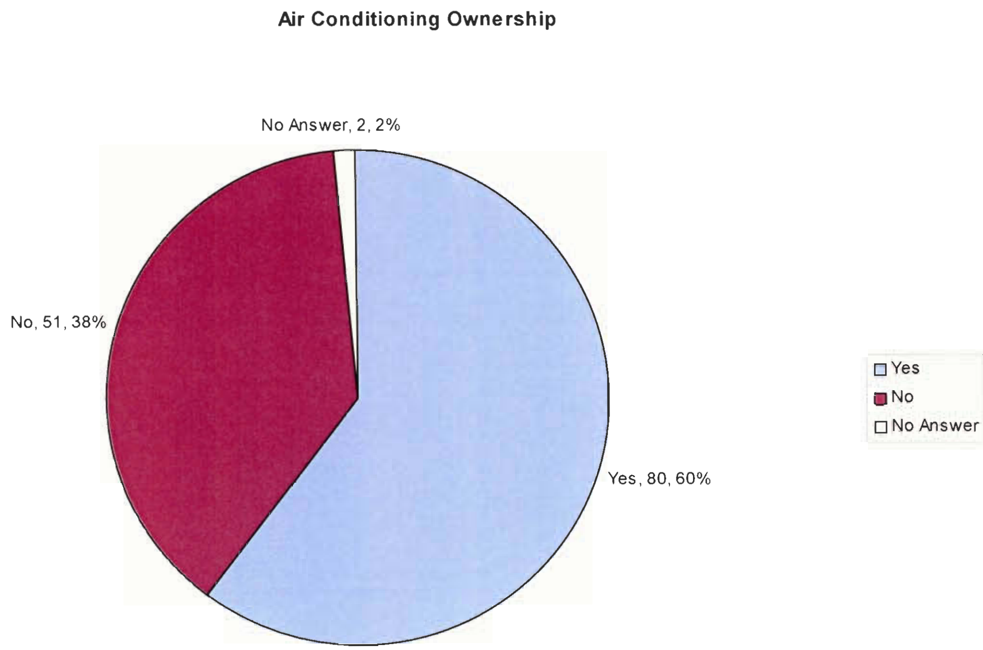


Figure 6.8 Ownership of Air Conditioning by Respondents

The second question we asked in part two of our survey dealt with the ownership of air conditioning devices. Figure 6.8 shows the ownership records for home air conditioning units: two people did not respond, 51 indicated they owned no air conditioning, and 80 indicated they had some form of air conditioning. For purposes of correlating our data, there are 0.611 air conditioners per household.

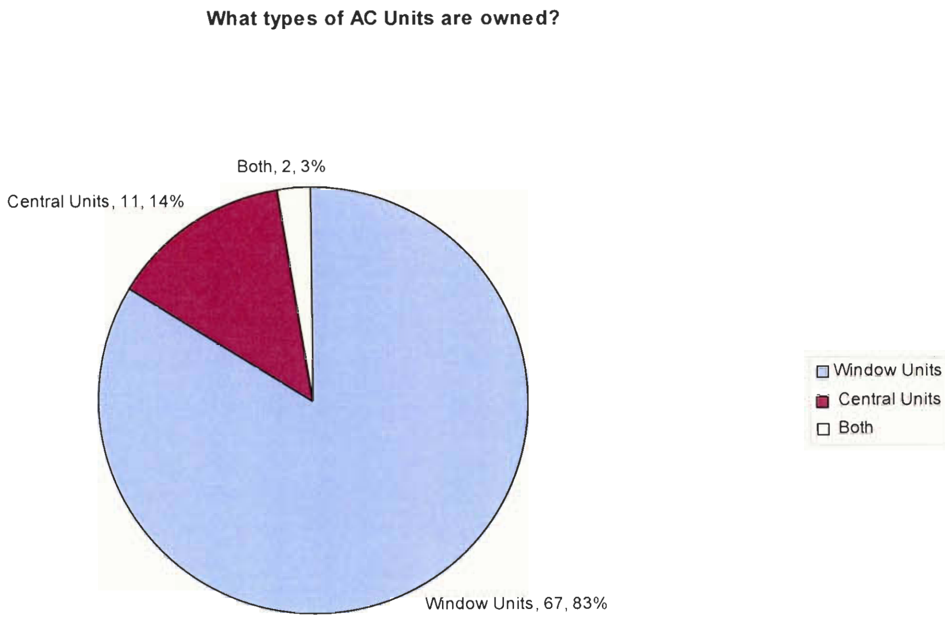


Figure 6.9 The types of air conditioning systems owned by respondents

In Figure 6.9, the results of our follow-up question on air-conditioner ownership are displayed as follows. Of the 80 responses, 67 indicated they had window air conditioning, 11 indicated they had central air, and only two indicated they had both window and central air conditioning. For our combined analysis, we can assume that there are .025 window and central air conditioners per houses with air conditioners, 0.138 central air conditioning units per houses with air conditioning, and 0.8375 window units per houses with air conditioning.

Combining the information in this follow-up question, we can figure that there are 0.8625 air conditioners per homes with air conditioning, and 0.163 central air conditioners per home with air conditioning. Finally, when combining this information with the information ascertained in the previous question, we can determine the average number of specific air conditioning units per home. By dividing 69 by 131, we get at least 0.526 window units per household on average, and by dividing 13 by 131, we get 0.099 central units per household.

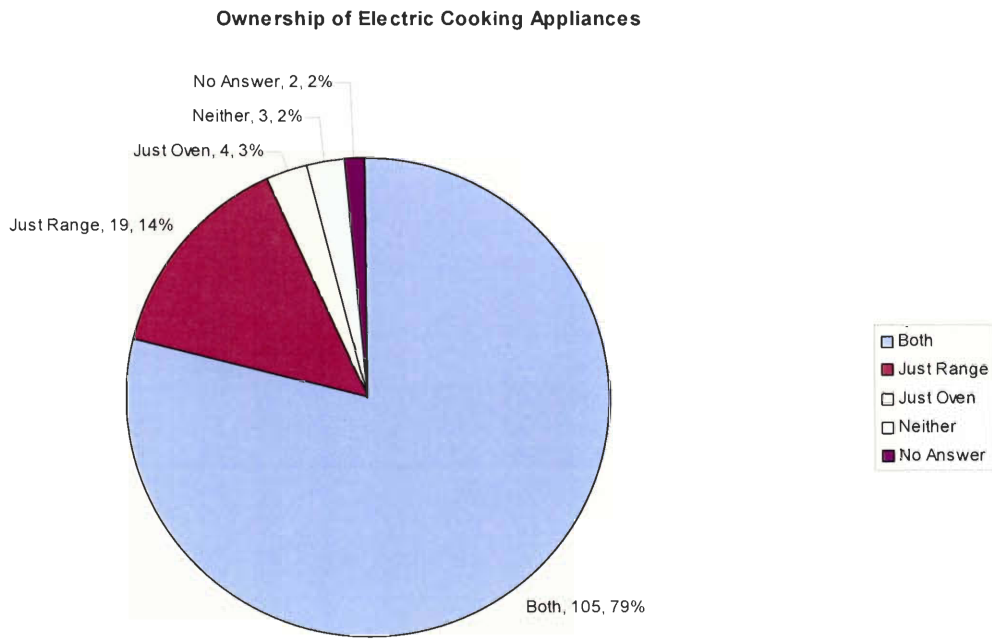


Figure 6.10 Electric Cooking Appliance Ownership

The results of the fourth question asked in Part 2 of our survey determine the ownership of electric cooking appliances, specifically ranges and ovens, in our target area. Only two of the respondents left this question entirely blank. The remainder of the responses was distributed as shown in Figure 6.10: 105 respondents indicated they owned both an electric range and oven, 19 indicated owning only an electric range, four indicated owning just an electric oven, and the remaining three indicated they owned neither an electric range nor an electric oven. After removing the non-responses from our set, we can compute the combined statistics for our comparison with the Massachusetts

Electric Company data. Therefore, for purposes of use in our combined analysis, there are 0.947 electric ranges per house, and 0.832 ovens in each house.

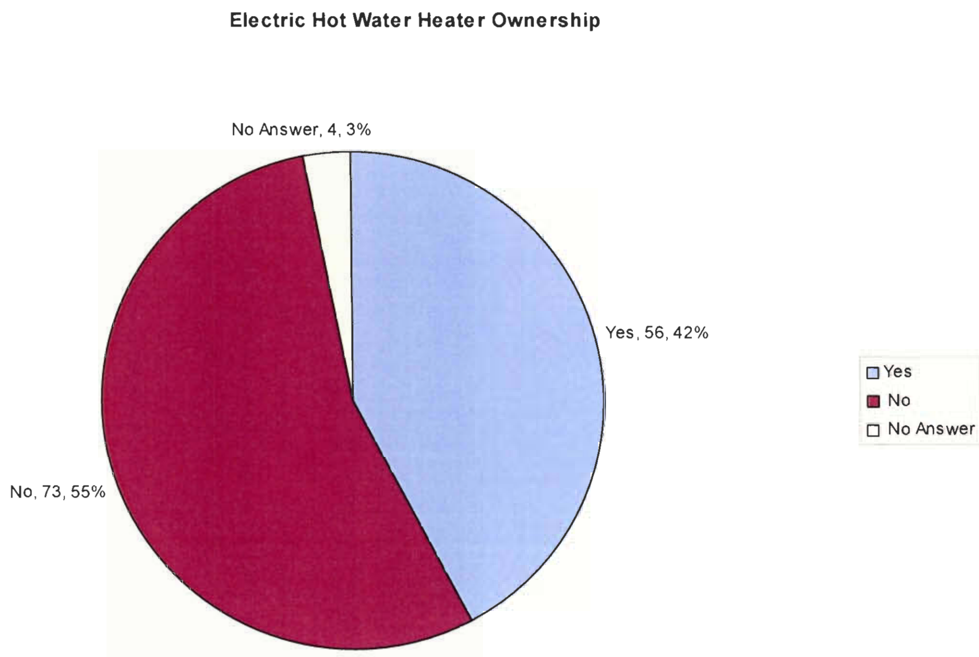


Figure 6.11 Electric Hot Water Heater Appliance Ownership

The ownership of electric hot waters heaters, the information obtained through question number 4 of part 2 of our survey is displayed in Figure 6.11. Four people failed to indicate a response to this question, 56 people indicated they did have electric hot water heaters, and 73 people indicated they did not own an electric hot water heater. For our combined analysis, we can throw out the four non-responses, and assume 0.434 electric hot water heaters per household.

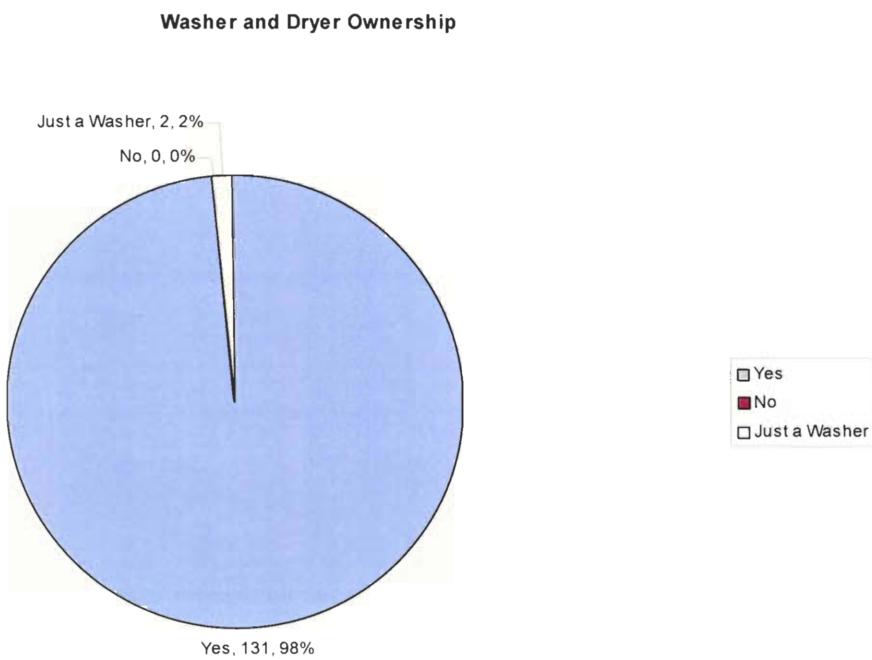


Figure 6.12 Washer and Dryer ownership among respondents

No respondents indicated they did not own a washer and dryer. There were two 'write-in' responses that indicated that the respondents did not own a dryer, or that their dryers were broken (see Figure 6.12). For purposes of analyzing the Massachusetts Electric Company data with this data, we can assume that there are 0.985 dryers and 1.000 washers per house.

The results for the follow-up question we asked on the power of the respondents' dryers had similarly lopsided results (see Figure 6.13). One hundred twenty-nine out of 131 people indicated their dryer was electrically powered. For purposes of comparison with the Massachusetts Electric Company data, we can assume that there are .984 electric dryers per houses with dryers, or 0.970 electric dryers per house.

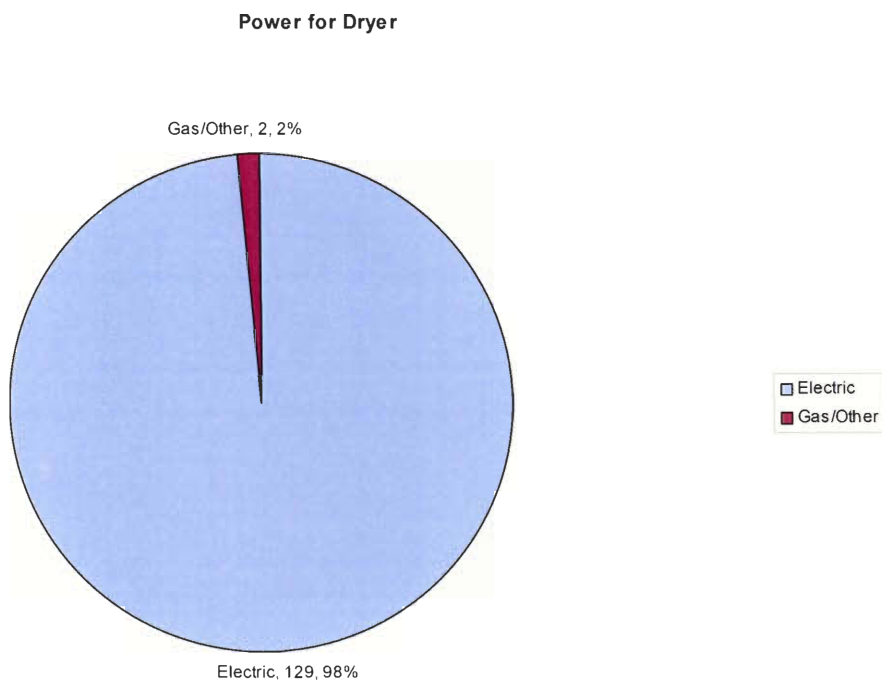


Figure 6.13 Respondents with electricity powered dryer

Because the manner in which we asked the question on refrigerator and freezer ownership was an open-ended question, rather than allowing the subject to choose from a range, these results must be presented in a different manner (See Tables 6.4 and 6.5). All respondents to the survey indicated that they owned refrigerators: most people owned one, several people owned two, and three different respondents indicated they owned three refrigerators. On the other hand, most of the homes which responded to the survey did not have separate freezers. Because a number of the respondents to our survey owned more than one refrigerator, the average number of refrigerators per home is 1.323. The average number of freezers per homes with freezers was 1.053, but the number of freezers divided by the number of homes who responded to this question gives us 0.301 freezers per home.

Table 6.4 Descriptive statistics on Refrigerator ownership

Refrigerators	
Mean	1.323308271
Median	1
Mode	1
Standard Deviation	0.515647169
Range	2
Minimum	1
Maximum	3
Sum	176
Count	133

Table 6.5 Descriptive Statistics on Freezer ownership

Freezers	
Mean	1.052631579
Median	1
Mode	1
Standard Deviation	0.226294286
Range	1
Minimum	1
Maximum	2
Sum	40
Count	38

The penultimate question we asked of the respondents was whether or not they owned pools or Jacuzzis, and how often they operated. There was only a single participant who did not respond to this question. We found a surprisingly large number of the respondents owned swimming pools, while very few of them owned Jacuzzis (See Figure 6.14). Out of the 132 respondents, 38 of them owned swimming pools, nine of them owned Jacuzzis, and three of them owned both pools and Jacuzzis. For purposes of correlating the Massachusetts Electric Company data with our survey data, we can assume that there are 0.311 pools per house, and 0.091 Jacuzzis per house.

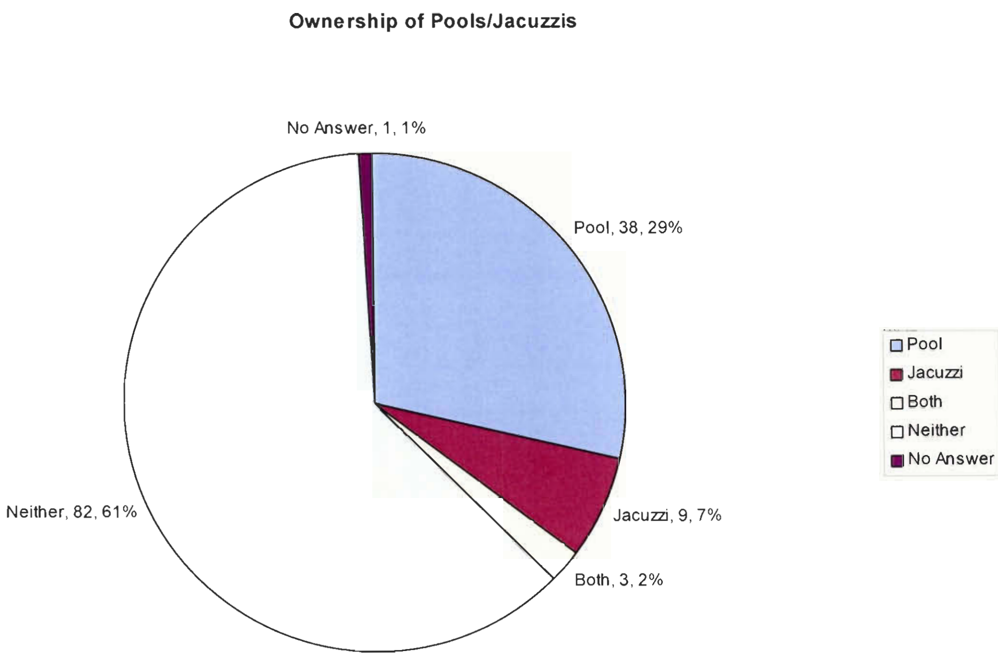


Figure 6.14 Respondents with Swimming Pools or Jacuzzis

The follow-up question was asked to determine the amount of time the Jacuzzi or pool was on during the year. As evidenced in Figure 6.15, the overwhelming majority of pool or Jacuzzi owners indicated that they did not in fact leave them on all year. Per house with a pool or Jacuzzi, only 0.140 are left on year round. This means that per house total there are only 0.053 Jacuzzis or pools on year-round.

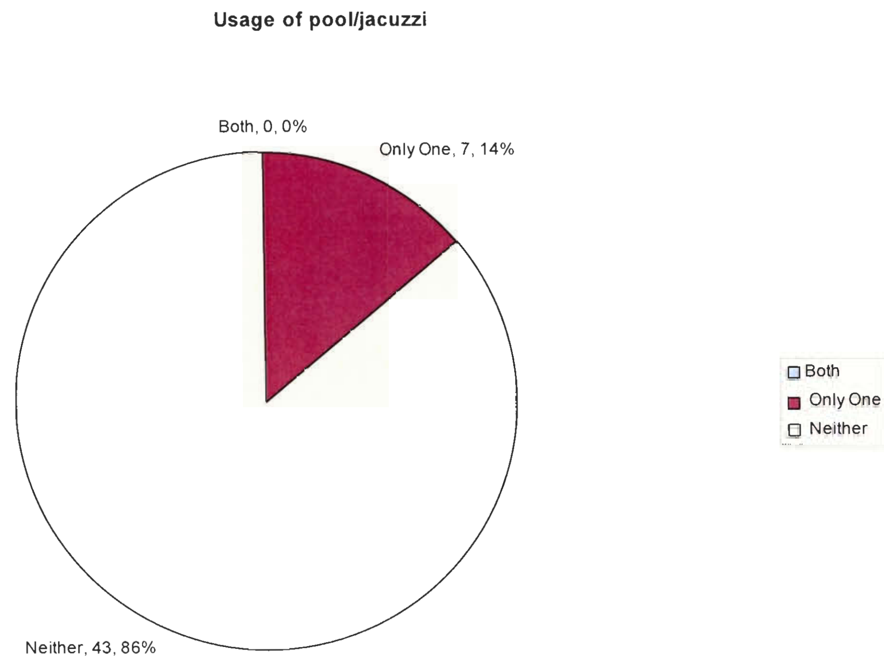


Figure 6.15 Time of activity for pool or Jacuzzi

The final question asked was to determine whether or not the respondents owned workshops. No one neglected to mark an answer on this question, and approximately one quarter of the respondents indicated they did have a workshop at their house, as indicated in Figure 6.16. There is really no way to correlate this with the Massachusetts Electric Company data, but if we were to try, we could figure there were 0.271 workshops per household.

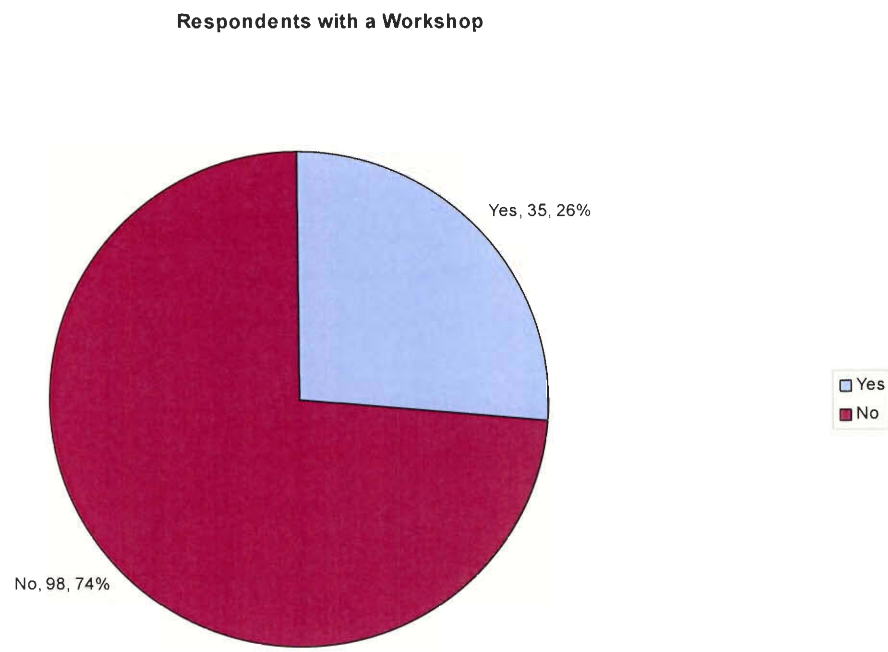
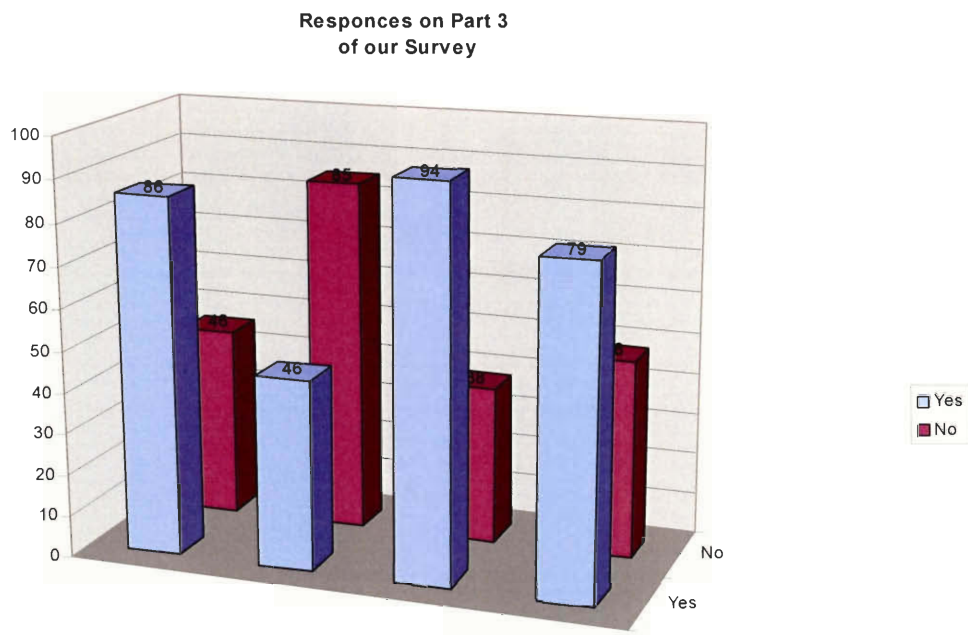


Figure 6.16 Respondents with a workshop

6.2.2.3 Survey Part 3 Results

The results for Part Three of our survey are presented in Figure 6.17. In this section we attempted to gauge the consumers' understanding of their power bills, and whether or not they were interested in a modified bill. Our first question, whether or not the respondents knew if their last power bills were estimated or read, was answered by all but one of the respondents. Eighty-six people (65%) indicated they knew whether their power bills were estimated or read, and 46 indicated they did not. The second question asked consumers directly whether or not they felt they understood their power bills. The results for this question were almost the inverse of those for question one. Two people elected not to answer this question, and of those who responded, 46 said they felt they understood their bills, and 85 (64.9%) said they felt they did not understand them



	Question 1	Question 2	Question 3	Question 4
Yes	86	46	94	79
No	46	85	38	48

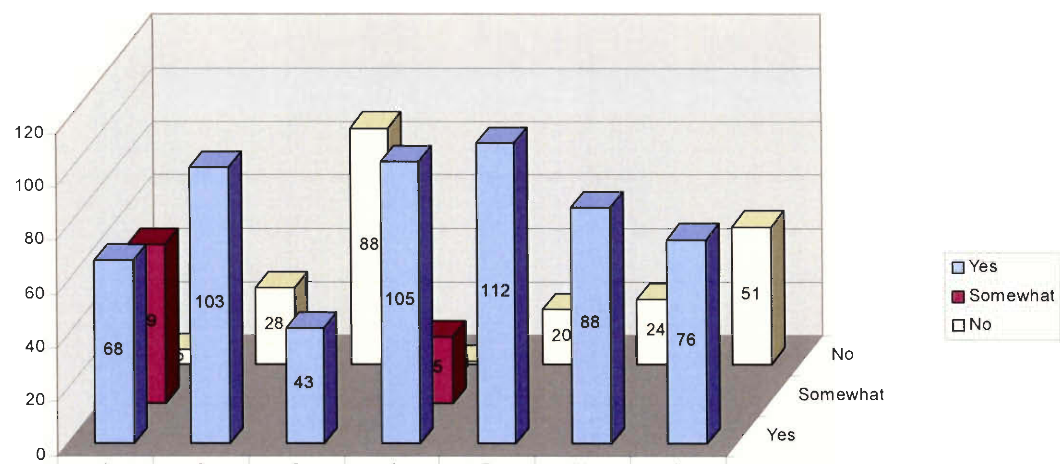
Figure 6.17 Responses to Part 3 of Auburn Survey

The third question on whether or not the respondents were interested in a guide for the current power bill was even more lopsided than the previous two for this section. Of the 132 people who answered this question, 94 (71.2%) indicated they would like a guide for the current power bill, and the other 38 said they did not want a guide. The final question of Part Three of the survey had similar, though less pronounced, results as question three. Of the 133 surveys returned, 6 people chose not to answer this question, or indicated in the margins that they did not know whether or not they would be interested. Of the 127 responses, 79 people (62.2%) indicated they would like to see the bill redesigned, and 48 people indicated they did not feel a redesign was necessary.

6.2.2.4 Survey Part 4 Results

The results for Part Four of our survey (see Figure 6.18) are presented in a very similar fashion to the results for Part Three. The first question revealed an even split between people who thought they were energy-conscious and people who thought they were somewhat energy-conscious. For the second question, 103 out of 131 people said they looked at the energy consumption of appliances before they purchased them. On the third question however, the majority of people, 88 out of 131, said they did not take advantage of some Massachusetts Electric Company offers for energy audits. On the fourth question, 105 people indicated they did turn off appliances to save electricity, 25 said they did sometimes, and only one person indicated they did not care about turning off their appliances to save energy.

Responses to Part 4 of our Survey



	1	2	3	4	5	5b	6
Yes	68	103	43	105	112	88	76
Somewhat	59			25			
No	5	28	88	1	20	24	51

Figure 6.18 Responses to Part 4 of our Survey

On the fifth question, 112 of 132 people said they did know whether or not their insulation was adequate. Of those 112 people 84 of them indicated they did have proper insulation, and 24 said that their insulation was not adequate. The final question of the survey was an attempt to gauge interest in the device we were designing for Goal Three of this project; 76 out of the 127 people who responded to this question indicated they would be interested in a device to gauge their electrical usage between electric bills.

6.2.3 Massachusetts Electric Company Results

In order to initially present the Massachusetts Electric Company data, we first had to allow for equal weighting among each of the houses, which we could not be assured of due to the different billing periods, and irregularities in the data. Because the purpose of the Massachusetts Electric Company data is to correlate with the survey data, there are few results presented here other than summary statistics on yearly averages and billing intervals.

The first thing we had to calculate to determine the yearly averages for each home was the billing intervals for every house. The average billing interval was 31.11 days, but the standard deviation was 3.89 days, which indicates a fairly high variation in the billing periods. The descriptive statistics for our billing period calculations are displayed in table 6.6.

Table 6.6 Billing Period Statistics

Billing Periods	
Mean	31.10932
Median	31
Standard Deviation	3.894207
Range	80
Minimum	11

Maximum	91
Sum	187247
Count	6019

Using the billing periods calculated above, the average daily consumption for each home can be calculated. After multiplying the daily consumption by 365, we are left with the yearly averages we hoped to obtain. For the houses in the data given to us by Massachusetts Electric Company, the average consumption is 9172 kWh of electricity per home, but with an exceptionally large standard deviation, indicating a large amount of variation among the houses. The descriptive statistics for our yearly averages are displayed in table 6.7.

Table 6.7 Yearly Statistics

Yearly Averages	
Mean	9171.769913
Median	8057.847411
Standard Deviation	5427.627212
Range	51165.5689
Minimum	148.1880109
Maximum	51313.75691
Sum	4778492.124
Count	521

6.2.4 Correlation of Massachusetts Electric Company and Survey – Part 2

The results for the correlation of the Massachusetts Electric Company data and the data we obtained in the surveys is best displayed as a table (see Table 6.9). The information we obtained from the surveys, that we then calculated into a per house average, is used to determine the average usage by particular appliances per home; that information is displayed in the Appliances/Home category. The usage range column contains ranges for expected yearly kWh usage for the appliances we asked about in our survey. Using these ranges we estimated the average annual usage for the specific appliances. All of these estimates are based on the most energy-efficient appliances, to determine a minimum amount of electricity the consumers could be using. The average appliances per home multiplied by the estimated use then yields the average usage per home for those specific appliances; this information is presented in home usage. The one appliance that we did not ask about was 'miscellaneous lighting expenses.' We felt that this would be fairly similar for all the homes, and that pretty much every house needs lighting. After summing all of the average annual usage per appliance, we obtain a composite figure for the average amount of electricity the houses in our area should be using. For comparison purposes, the average number of kWh a year per house used in the area we surveyed is also included. The differences between these two figures will be discussed in the analysis section of the paper. Finally, the sources for our estimated usage and the usage ranges are included as the last column of the table to help ease the burden of examining the location of our figures.

Table 6.8 Average use by appliance per house (kWh are yearly unless otherwise noted)

Appliance	Usage Range	Estimated Use	Appliances /Home	Usage /Home	Source
Fan	56-182 /Month	540	0.8	432	www.lincolnelectric.org/watts.htm
Heat	810-1620	1620	0.2	324	www.we-energies.com/house/energy/appliances.htm
Window	364-1120	455	0.526	239.33	www.we-energies.com/house/energy/appliances.htm
Central	1335-4385	1335	0.099	132.165	www.we-energies.com/house/energy/appliances.htm
Range	780-1200	780	0.947	738.66	www.lincolnelectric.org/watts.htm
Oven	327	327	0.832	272.064	www.eren.doe.gov/buildings/consumer_information/ovens/ovenques.html
Hot Water	3000-4800	3864	0.434	1676.976	www.washingtonco-op.com/pages/appuse3.htm
Washer	282-1560	282	1	282	www.eren.doe.gov/femp/procurement/clothes.html
Dryer	438-1456	1056	0.97	1024.32	www.austinutilities.com/Energytips/appliance.html
Fridge	510-1920	512	1.323	677.376	www.eren.doe.gov/femp/procurement/refrig.html
Freezer	290-2400	900	0.301	270.9	www2.sdge.com/sdgeres/library/newpages/refrfrez.asp
Pool	500-4000	1500	0.311	466.5	Tables

Jacuzzi	1500-4000	2300	0.083	190.9	Tables
Lighting	1296	1296	1	1296	www.lincolnelectric.org/watts.htm
Sum of Estimated Usages / House				8023.191	
Actual Total Usage				9171	

6.3 Goal 2 – Usability Study Results

The results of the usability study are presented in brief here. If the reader wishes to examine the full results, they are located in Appendix B of this paper. Table 6.10 clearly shows the results of each of the questions when asked of each of the subjects. In the analysis section of the paper, we have clearly identified all of the difficulties subjects had with different parts of the bill. The question that gave the most people the most trouble was Question 5, the question on the calendar on the bill. The easiest question on the test for the subject to answer was Question 1, locate the amount of money that was owed that month. The remainder of the questions for the usability test lie somewhere in between these two in difficulty. The difficulties and possible causes of these difficulties will be discussed in detail in the analysis section of the paper.

Table 6.9 Results of Usability Testing

	Question 1	Question 2	Question 3	Question 4	Question 5	Question 6	Question 7	Question 8	Question 9
Subject 1	Correct	Difficulty	Correct	Correct	Correct	Difficulty	Difficulty	Correct	Difficulty
Subject 2	Correct	Correct	Difficulty	Difficulty	Difficulty	Correct	Correct	Correct	Difficulty
Subject 3	Correct	Correct	Difficulty	Correct	Correct	Correct	Correct	Correct	Correct
Subject 4	Correct	Correct	Difficulty	Difficulty	Correct	Correct	Correct	Difficulty	Correct
Subject 5	Correct	Difficulty	Correct	Difficulty	Correct	Correct	Difficulty	Correct	Correct
Subject 6	Correct	Correct	Correct	Difficulty	Correct	Difficulty	Difficulty	Correct	Correct
Subject 7	Correct	Correct	Correct	Difficulty	Correct	Correct	Correct	Correct	Difficulty
Totals	**No Difficulties**	**Two Difficulties**	**Three Difficulties**	**Five Difficulties**	**One Difficulty**	**Two Difficulties**	**Three Difficulties**	**One Difficulty**	**Three Difficulties**

6.4 – Device Design

6.4.1 Interface Design

The actual design for the interface of the device takes on two different forms. First, the external interface of the device is designed to allow the user to communicate his requests to the device. The next facet of interface design is the on-screen layout, which allows the device to display results to the user.

The layout for the external interface of the device is kept as simple as possible. The buttons are marked with text, as well as with symbols or colors that would evoke the user's knowledge of past experiences. The left and right keys have arrows pointing the directions they intend to go, and the accept and cancel keys are marked green and red respectively. This design allows users to relate some knowledge they already have to the use of this interface. A sketch of our proposed design is displayed in Figure 6.19.

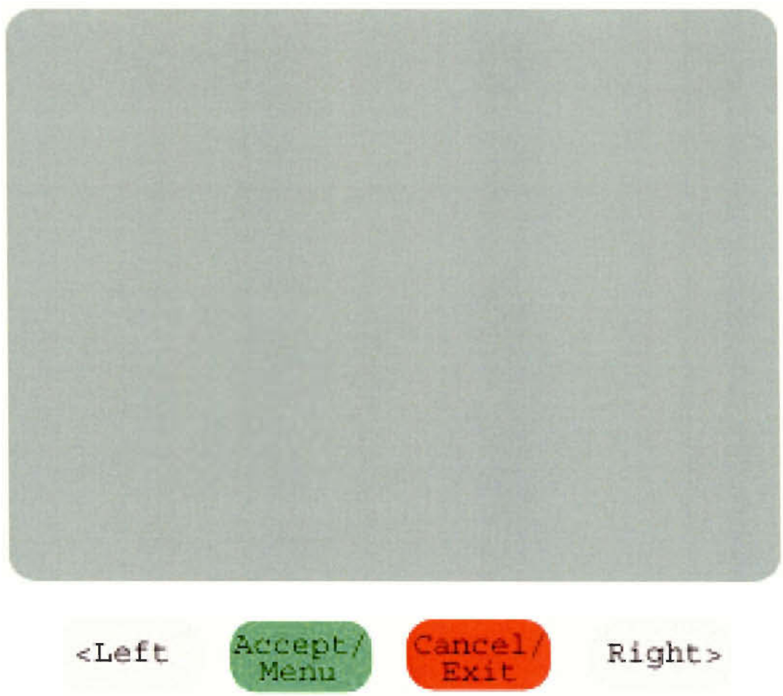


Figure 6.19 External Interface Sketch

The second general phase in the interface design is determining the on-screen layout of the device. The blueprint for the layout we have decided on is displayed in Figure 6.20. As this is the part of the interface that will communicate back to the user, it is important the information be displayed clearly and concisely, but in a simple enough manner to be readable at a glance. The first thing one probably notices about our screen is the inclusion of a graph. The intent is for the graph to allow the user to see when he is using the most electricity, and should be fairly adaptable to time periods, displaying all ranges from hour by hour to month by month. The second section of the screen that we have included in this blueprint is a static screen, displaying as much pertinent information to the user as possible, including the date, time, usage, and estimated bill. Finally, the last two sections which have been laid out in this blueprint are the menu location and the general display location. The menu will be the primary location for the user to interact with the screen, and the result of those interactions will be displayed in the general display area.

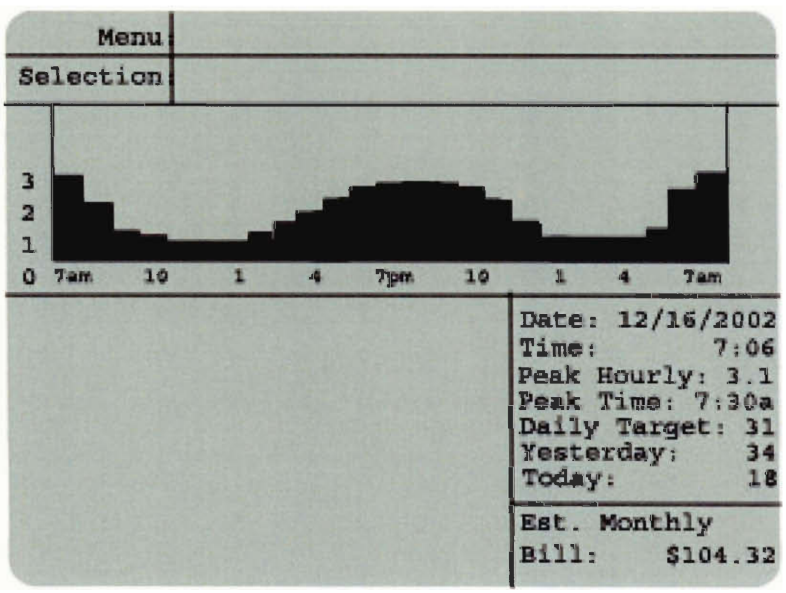


Figure 6.20 On Screen Interface Blueprint

6.4.2 Menu Design

In designing the menu interface for this device, we tried to keep complications to a minimum. We chose to implement our menus in a tree structure, to ease the cognitive processing load, and keep the number of elements below the hrair limit. The tree structure for our menu is displayed in Figure 6.20. The head node in the tree structure, Menu Root, will not actually be displayed to the user, but is used in our graph to indicate where the menu begins. The rest of the elements in the tree will be displayed to the user on the 'Selection Bar,' while the 'Menu Bar' area of the screen will contain the name of the current menu. The user will use the buttons on the hardware to scroll left to right, in order to select the menu they wish to access. That process repeats until the user reaches a leaf node of our tree structure.

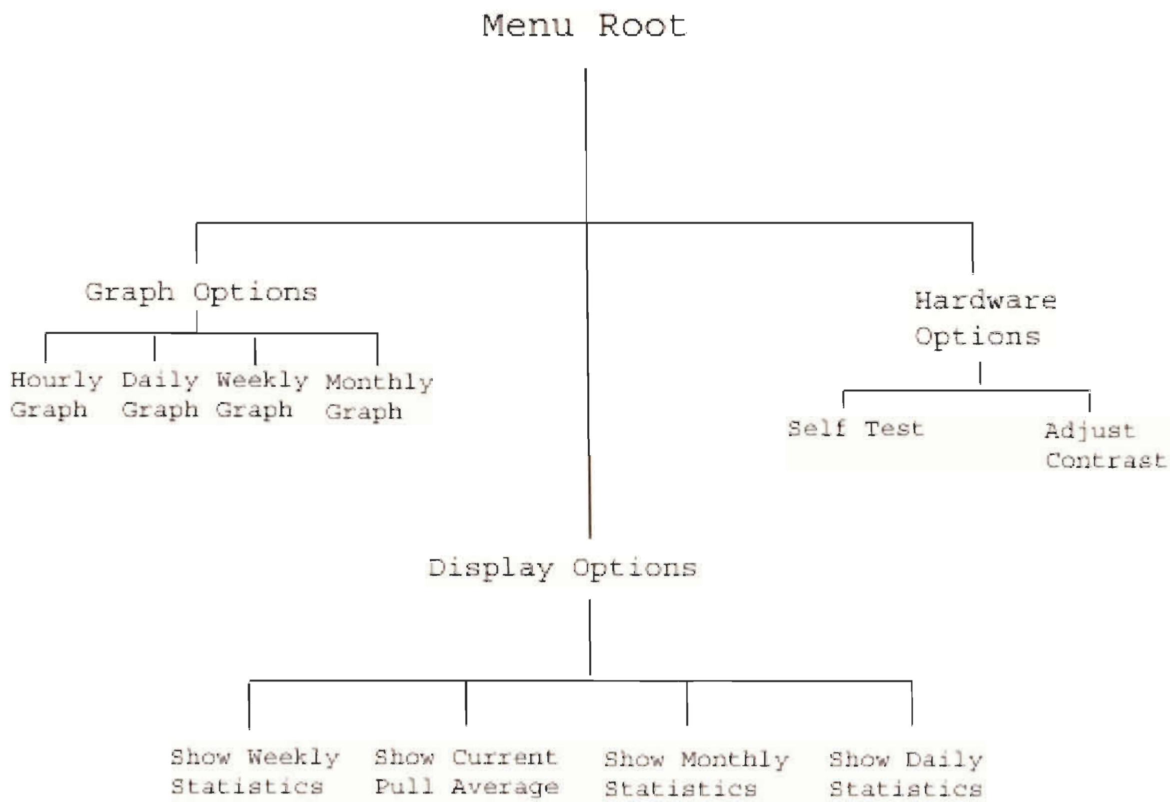


Figure 6.21 Menu Tree Structure

The groupings for the menu items we have selected in the tree structure are based largely upon where the user might expect to locate certain items. Options such as hardware self-test, contrast adjust, or any other options that deal specifically with the hardware, would be located under 'Hardware Options.' Following these lines, if the user wished to change the graph or the statistics displayed in the display section, he might think to look under 'Graph Options' and 'Display Options' respectively. By keeping the tree shallow but narrow, we ensure not only quick navigation through the menu, but an easier learning experience for the novice user.

Figure 6.22 Storyboard of sample user interaction. In chronological order, they should be read upper-left, lower-left, upper-right, lower-right.

In order to give a better indication of how the user will navigate the interface, we have prepared four storyboards, displayed in Figure 6.22. The top left figure represents the interface at rest, before any user input. After the user indicates he wishes to access the menu, the screen in the lower left-hand corner is what he would be presented with. Upon selecting display, to change display options, the user will then see the third screen, in the top right-hand corner of Figure 6.22. Because there are more menu options than fit on the screen in this example, ellipses and an arrow indicate the menu is continued off the screen. When the user makes his selection on the leaf node 'Monthly Statistics,' he is returned to the rest state of the interface, with the data he requested in the 'General

Display' section. While this interface is simple, it has a number of capabilities, and is also quite extensible.

6.4.3 Device Cost

The installation of a device that would provide daily feedback to the consumer about his electrical consumption would involve costs of materials and labor. An installation of this type would require an electrician licensed in the same state, which is required by the National Electrical Code (NEC).

Materials necessary for this installation would include small gauge signal wire to run from the main electrical panel to the place where the device would be located. A suitable wire for this installation would be #22/2 or #22/4 insulated telephone wire. A wire labeled #22/4 means that there are 4 individual wires in the cable and each of them would be of size #22.

Another material needed would be a doughnut-shaped coil that would wrap around the service entrance conductors (main incoming wires). This coil would work just like an amprobe, which measures current by using induction. The coil would step down the voltage and send a signal current through the wires to the device mentioned.

In some cases low voltage wires would not be able to be connected directly to the main panel, due to various laws in the NEC. In these cases larger wires would have to be connected to the coil mentioned and they would have to be brought outside the panel to a separate junction box where they would then be connected to the smaller signal wires. This case would involve a short length of #14/2 non-metallic sheathed cable or three #16 THHN wires to bring the signal current out of the panel. The wires would be encased in a short piece of pipe called a nipple, connected to the panel on one side and to a small 4" by 4" junction box on the other. If #14/2 cable is used two connectors can be substituted for the nipple.

The costs of all these materials would be relatively low. Number 22/2 wire can range from $0.05 to $0.10 per foot, and the combined cost of a junction box, nipple, and short lengths of larger wire would be under $10.00. A coil like the one mentioned has not been made for this purpose so its cost is not known, but similar coils cost under $20.00.

The other factor in installation of the device is the labor costs. A licensed electrician can cost anywhere from $50-$75 per hour, and the length of a job like this can vary greatly based on where the consumer wants the device mounted and the construction type of the house. An approximate job time for this installation would be 3-4 hours.

While we are able to determine the approximate cost of the device installation, it is a more difficult proposition to determine the cost of the actual device. For purposes of comparison, we are assuming the hardware required to implement the device would be similar to the hardware in a graphing calculator. The screen, the memory, and the processor could all be identical; the only difference would be in the software, and the IO interface for the hardware. All in all, this device might cost the consumer between $250 and $600, depending on the actual installation time, the hourly rate of the electrician, and the cost of the hardware.

7 Analysis

7.1 Introduction

The analysis of the information presented in the Results section of our paper is a fairly simple proposition. By examining the figures, we see definite trends, including: desire for a bill redesign or guide, desire for a device to help consumers gauge their electric usage, and a measurable amount of electricity wasted by consumers in general.

7.2 Analysis of Survey Data

7.2.1 Introduction

The analysis of the survey data can really most easily be broken down into an analysis of the responses to our survey, and then an analysis of the responses for the four parts the survey was divided into. In general the results support to differing degrees a number of ideas we have had since the beginning of the project.

7.2.2 Response Rate

According to our research, we should have expected a 60% response rate in a mail survey of the general population, given the use of personalized cover letters, attractive questionnaires, and follow up contacts (Salant and Dillman, 1994). Unfortunately, for various reasons, we only received a 50% response rate.

The first reason for nonresponse in our survey is that the some of the questionnaires did not reach the respondents, not giving them a chance to return questions. Because we distributed the surveys by hand, without stamps on the outside envelopes, postal employees removed 29 surveys from various mailboxes. Thus, those 29 respondents didn't get a chance to answer the questionnaires. This is a regulation of which we were unaware, but most likely played a major role in nonresponse.

The most important difference between good mail surveys and poor mail surveys is the extent to which researchers make repeated contact with nonrespondents. There is a reasonable sequence of events to make repeated contact with the nonrespondents (see Section 4.2.2). Unfortunately, because of time constraints, we were not able to mail reminder cards, follow-up letters, and second questionnaires to the nonrespondents. While Massachusetts Electric informed us we would be given our data in a timely fashion, this in fact did not happen. Therefore, plans we had made months in advance of our survey had to be modified to accommodate for this tardiness. The post office and lack of reminder postcards and letters all may have contributed to nonresponse in our surveys. However, perhaps the most likely reason for nonresponse was that the respondent chose not to fill out the questionnaire, or was unable to answer the questionnaire. Despite these setbacks, if we discount the 29 surveys which were confiscated by the post office, our response rate was 55%.

Time constraints also played a significant role in our analysis of the data. An overwhelming majority of the 148 surveys which were received from respondents arrived in the three weeks following the delivery of the surveys. There were however, 15 surveys that we received after we had completed the analysis of our data, and thus were not included in our results or analysis. This in turn put our overall usable response rate at

44.6%, and a usable response rate of 49.4% when disregarding the surveys we know never reached the recipients.

7.2.3 Responses to Survey

The questions that we asked in the first part of the survey were intended to give us background information on the type of consumers who were responding to our questionnaire. In other words, are results are primarily applicable to the homes we surveyed; primarily middle-class homes, with approximately three people living in each home

While the first section of the survey provides primarily background information for possible correlation with parts three and four of the survey, the results for the second section were earmarked for correlation with Massachusetts Electric Company data. While the results of the survey from the pretest are available for this correlation, the fact that we have no electrical data from the pretest area makes the use of that data unnecessary. The analysis of the results obtained in the correlation is discussed in detail below in Section 7.4.

While Part 2 of our survey is only being used in correlation with the Massachusetts Electric Company data, it is important to discuss some of the sacrifices we made in the design of our survey. We decided to keep the survey length to a minimum, because we felt our response rate could be hurt by a survey that was too long. In keeping with this, we tried to ask as few questions on appliances as we could without losing appliances that were valuable to our results. In short, all of the appliances we asked about were well placed on the survey, with the exception of the final question in part two.

As it turns out, there are not raw numbers for the kWh use of a workshop in the residential area. We feel this question could have been better replaced by asking about a waterbed heater. Despite the fact that it may sound odd, a waterbed heater was the highest energy-consuming appliance we left off the survey. A more detailed look at some of the trade-offs we made is presented in Section 7.4.

The results from Part Three of both the pretest and the actual survey are quite applicable to the goals we set forth in this project. In both cases, customers indicated several important facts about their understanding of the power bill. A clear majority of respondents knew whether or not that last bill was estimated or read, which indicates a degree of comfort on their part when working with their power bills. Despite this fact, the responses to the second question for both surveys indicate to us that the consumers are typically not comfortable with their bills. The final two questions of Part Three echo this sentiment. The responses to Question Three clearly indicate that consumers feel a guide to their power bills would be beneficial, while Question Four tells us a smaller majority would be interested in the redesign of the bill. Though the interest for a bill guide was high, we decided to implement minor changes to the design of the bill instead, because the original bill had some fairly serious design flaws.

Finally, Part Four of the survey, though slightly different between the pretest and the Auburn survey, gives us an intriguing look into the way that consumers view themselves with regards to conservation of power. While most respondents in both surveys indicated they felt they were either conservative with energy or somewhat conservative, the numbers for the responses to the questions following that paint a somewhat mixed picture. Most of the respondents from both studies indicated they looked at energy star ratings when purchasing appliances, but less than half of our respondents had taken advantage of free offers by the electric company for energy audits and other programs geared towards energy conservation.

The responses we received for the third question were for the most part exactly what we expected. Whether or not a person is concerned with conserving electricity, it is prudent to keep appliances off when they are not being used. The answers to the fifth question, and the follow-up on that question were not surprising either. The majority of people knew how their house was insulated, and the majority of those people indicated their house was properly insulated.

Finally, the response to the sixth and final question on part four of the survey is directly applicable to the design of a device to help consumers gauge their power usage. The positive response received during the pretest of our survey spurred us on to design the device, and the positive results obtained during the Auburn survey only reinforced our decision.

All in all, the picture painted by the data we obtained through the surveys is an interesting one. While the two neighborhoods we surveyed were in totally different parts of the country, the answers to the questions in parts one, three, and four were all very similar. In general, consumers feel that their power bills are confusing, and would definitely be interested in enhancing their understanding of their bills by some means or another, be it by a guide to or a redesign of the bill.

In addition to this, the respondents made it very clear they felt they were interested in conservation, but they had not taken every step available to them to conserve electricity. It might be prudent for the power company to more aggressively market some of their conservation programs, but this will be discussed in the recommendations section. While this is not a surprising conclusion, we were not necessarily expecting such a large percentage of people to rate themselves as energy-conscious.

7.3 Analysis of Massachusetts Electric Company Data

The analysis of the Massachusetts Electric Company data is a fairly simple proposition when the data are taken on their own. The data presented in the results section indicate an average yearly kWh consumption of just less than 9200, with a very large standard deviation. In general, this means that the customers in this area are extremely varied in their usage of electricity, despite the fact they are all single residence homes.

The first point of interest was the large variation in the number of days during each billing period. The average number of days was right on a par with the number of days in the average month. However, by examining the range, minimums and maximums, the immense variation in the length of billing periods is revealed. Some houses had billing periods as short as 11 days, while others consistently had billing periods well over two months. This large variation is mostly responsible for the standard deviation over three.

By simply examining the minimum and maximums for the yearly averages, one might guess there are outliers that can be removed. For simplicity's sake however, we have decided not to remove outliers. The Massachusetts Electric Company assured us that there were no multi-residence homes and no commercial buildings included in our data, but at the same time it is highly unlikely that a residential home would use 50,000+

kWh of electricity per year, almost five times the average we determined. Along this same line, it is also highly unlikely for a home to use only 143 kWh of electricity per year. However, removing outliers is a complicated process, and selecting criteria by which to include or exclude data might not exclude some data which were clearly outliers.

Having decided not to remove outliers, our average for yearly consumption comes out to 9172 kWh. While we do not have a baseline for comparison, the correlation which is discussed below confirms this as a reasonable estimate for yearly usage in our target area. The importance of this figure will be examined further in the combined data analysis section. The error of the Massachusetts Electric company, with a sample size of 521 houses, is approximately 4.29% at a 95 % confidence level, and 5.65% on a 99% confidence level.

7.4 Combined Data Analysis

As previously mentioned, the correlation between the Massachusetts Electric Company data and the data we obtained in the surveys plays a very large role in our project. The results obtained when correlating these results look very promising, but several points must be discussed before declaring our study an overwhelming success.

First and foremost, this is only an attempt to correlate two different samples we obtained independently. The first sample, a simple random sample performed at our request by Massachusetts Electric Company of houses in a specific area, did not contain identifying information for each house other than the name of the street from which it was pulled. In the second sample, we performed a stratified random sample using the streets as the distinct strata. We took an approximate number of houses in the Massachusetts Electric Company data from each street, and attempted to survey an equal percentage of the houses from each street. We distributed 298 surveys, and 133 of those were returned to us, which gave us a confidence interval of over 8.5%. Due to the inherent error in both of the samples, the correlation of the two is bound to contain some error. Because we cannot determine the amount of error in the Massachusetts Electric Company data, we cannot determine the exact error of our correlation; but suffice it to say that the error is going to be above 8.5%. While we can establish 8.5% as a lower bound on the error, we cannot establish an upper bound, though we are assuming the samples to be relatively accurate, and our correlation should follow along those lines.

The second point of interest to discuss deals not with our sampling procedure, but with our methodology for calculating the amount of electricity used by each home. When we designed the survey, we made sure to include as many of the 'large consumption' appliances as possible. The limitation on the number of appliances we asked about was based on our assessment of a respondent's willingness to answer, based on the amount of time required to complete the survey. Therefore we could not include the set of all possible appliances on the survey. Thus, the difference between our estimation of the usage by consumers and the actual usage as calculated from the Massachusetts Electric Company is partially due to unaccounted-for appliances. That being said, the majority of the energy use has been accounted for, and only a few appliances remain that would alter our findings. The difference between the actual usage and our estimated usage will give the amount of electricity which is possibly wasted each year. Thus, it can be said that our consumers probably waste between 0-1150 kWh of electricity per year on average.

Finally, the appliance estimates we performed were based on the most energy-efficient appliances. This fact alone might lead to an unrealistically low estimate of electrical energy that should be used by the average consumer. However, we may have somewhat over-estimated the use of heating and cooling appliances, assuming that consumers use both of them 5 months out of the year. At least for cooling appliances, this is a very generous estimate for the Massachusetts climate; thus our baseline usage estimate is probably accurate or slightly above the actual amount used by our consumers.

Having accounted for our error, and explained flaws in our method, it is important to say that our results should not be discounted. Much to the contrary, they should speak for themselves. The fact that the average use by consumers is 9172 kWh of electricity per years means that there are people using far greater amounts of electricity. Our findings in other parts of the survey would indicate to us that some people's energy use habits would be regarded as more conservative than others, and this fits with what we see in our results with the combined analysis. It is clear that while the use of electricity is close to our predicted results, consumers could still do more to conserve electricity, and solutions to this problem will be discussed in our recommendations section.

7.5 Analysis of usability test results

In this section, we will be analyzing the results from the usability section of our project. We will start by talking about the most frequent and problematic areas on the Mass. Electric bill. The first problem lies with the calendar located on the first page of the bill. The problem is that the calendar starts counting the months up from the bottom. The bill that was actually used in the study starts at the bottom with April 2000, and then goes to May, June, July, etc., up to the current month of the bill, which is April 2001. In the seven individuals whom we tested, only two of them actually understood how the calendar was laid out. To further increase the problem, the months are only listed by their first letters, so people got confused when they came to May, April, March, abbreviated on the bill as M, A, M. Quite often, we had the subject confusing March with May and vice versa.

Another problem with the bill was the wording for the explanations of the extra charges that are on the bill. In order to locate these explanations, the customer must flip over the bill. Then, even after reading them, most of our subjects had trouble understanding exactly what the explanation meant.

The third problem that we encountered was the whether the bill was standard offer service, or default. All seven of our subject did not know what the difference is, and most of them had trouble even locating where on the bill it specified what the service was. After we explained to each of the subjects what the difference between the two was, they were shocked to find how much more the default service is, and that you had to specially request the standard offer.

The next problem that we ran into was similar to the last problem, but this time it dealt with whether the bill was estimated or actual. Several consumers in our study found it difficult to determine whether their bill was estimated or actual

The next problem is with all of the charges that are listed on the bill. They are listed on the front side of the bill in a confusing array of many categories. For each charge, the consumer sees a decimal multiplied by the amount of KWh on the bill. Three out of the seven subjects asked us what KWh is, and then how the company computes this. None of the subjects actually knew that this was the unit of electricity that the whole bill is based on. Here the company needs to be more user-friendly with its explanations, even if it does mean using many more sheets of paper or an extra pamphlet with each bill explaining units, charges, base rates, etc.

The last problem that we encountered was that subjects couldn't locate the date that the bill is actually due on. It is very easy to see what dates their accounts were billed on, but you have to go into the calendar to see when your payment is due by so that you will not have any interest tacked on to your account. It seems possible that the company is doing this because they don't want to make it easy for the consumer to pay his bill in a timely fashion. Without being able to find out what the due date is, the consumer may become quite confused and frustrated with it, and possibly put it away and not make his payment by that date, and then the electric company can charge them interest rates.

These were all of the specific problems, but there were many general problems with the bill. When all of the subjects looked over the bill before the test, they had many questions about what this and that means, and all of the electric company's terminology. This was very hard to begin to try to explain to them, because it took our group substantial time to understand it ourselves. Clearly, this bill design cases some serious problems for consumers, and should be modified accordingly.

7.6 Analysis of Device prototype/design

A brief analysis of the device design presented in Section 6.4 gives us a good indication of how the device is likely to fare in a commercial setting. First, the cost of the device is going to be by and large the main factor inhibiting its widespread acceptance. Assuming the device will cost around $500, the consumer would have to be convinced that by using this device they would recoup this sum in a reasonable amount of time; from some information obtained in the literature review, this does not seem like a stretch.

The second factor that must be examined in the analysis of this device is the user interface we designed. Through the application of two simple performance metrics to this proposed interface, we feel the interface is likely to be successful. The first performance metric used when analyzing our interface is the number of actions required by the user to accomplish a specific task. This is extremely easy for us to compute, because the leaf nodes on the tree structure for our menu are all at the same depth. From the neutral screen, the user must press 'Accept/Menu' exactly three times. The number of left and right clicks necessary depend on the positions the user wishes to select in the menu, but assuming the cursor starts on the right, a maximum of four clicks to the right is required to reach any position in the tree. This means that a user must press a button between three and seven times to accomplish a specific action. This performance metric indicates our interface is not only fairly consistent, but also never requires any long sequence of key strokes to use.

The second performance metric we can apply to our interface is to count the number of actions required to recover from an error. There are two different types of errors a user can make: erring in his selection of a path in our menu tree, or erring in his selection of a leaf node in our tree. In the latter case, the number of actions required to solve the problem is the same as the number of actions required to use the interface. The former case requires much less effort to correct on the part of the user; he simply clicks the 'Cancel/Exit' button and reselects the proper path in the menu structure. This type of error correction requires one button to be pressed (twice if the user erroneously entered the menu, but we assume this is not likely because the buttons are useless outside of the menu). Therefore, error correction can require from one to seven clicks, which indicates that our interface is fairly forgiving. In other words, if the user does make an error, he can easily escape his mistake.

The final factor to examine when analyzing our interface is the data available to the user. By displaying information over varying time intervals, and allowing the user to view that information in a graph format, we feel this device would offer consumers an unparalleled look at their energy consumption. To our knowledge, there are not consumer products in production that are similar to this idea. In other words, there is little data on how the public will react to a device like this. However, the data obtained in Part Four of our survey indicated that the majority of consumers we surveyed would welcome the development of a device like this.

8 Recommendations

8.1 Introduction

Based on our research, and an analysis of the data available to us, we have several recommendations to help solve some of the problems that motivated this project. These recommendations include: allowing for a redesign or guide for the current electric bill, distributing appliance information and conservation pamphlets to keep consumers better informed of where they waste their energy, and finally the implementation of our design of a device to help consumers gauge their energy usage.

8.2 Goal 1: Recommendations

The first recommendation we will offer is the creation of a small pamphlet that could be handed or mailed out to homeowners. The pamphlet lists several energy saving tips for homeowners to follow and a write-up describing the pamphlet can be seen in Appendix C. The pamphlet is split up into two sections: tips for buying an appliance and tips for using appliances.

The first section of appliance tips involves things to look for when purchasing appliances. The results of our survey indicated that most people feel they are at least somewhat energy conscious. One hundred and three out of 131 people claimed that they looked at the efficiency of appliances they are thinking of buying. The first section of the pamphlet will help these people by showing them what to look for when shopping for an appliance.

The second section of the pamphlet lists tips for these people to use to save money with their existing appliances. Our survey also showed that many people own appliances where certain energy saving tips could be of great assistance. Most of these tips are just simple ways to better operate each appliance that could decrease kilowatt-hour usage and save the consumer money.

If the electric company wished to distribute a pamphlet like this, it may be expanded to include their offerings for energy conservation programs, and additional information they have found important during the life of these programs.

8.3 Goal 2: Usability Recommendations

In this section, we suggest that some changes must be made to the electric bill to increase its usability by consumers. The first recommendation that we offer is that the calendar should reformatted. We think that the calendar should be set up like a table, with the months listed on left going top to bottom counting chronologically through the months, and by each month the corresponding amount of kWh used should be listed. In this table the months should be spelled out more explicitly (they can still be slightly abbreviated for the longer months) so that the consumer can easily understand what month is what on the bill, not just the first letter. We feel that this will take care of the problem of the consumer not knowing whether they used more electricity than they did in the current month from last year. If this is accomplished, the user can see that they might need to cut back on electricity usage to save some money. This will give them a better understanding of the bill itself, which would allow them to conserve electricity.

The wording and the explanations of the bill and its charges need to be modified as well; one question that we asked on the usability study was "can you locate the energy conservation charge on the bill and tell us what it is." When this was asked, the subject obviously wanted to know what that charge was actually for, and the explanation reads like this: "Energy Conservation= The cost of demand side management programs offered by the company." This means that the company is actually charging the consumer for conservation programs that are currently running. This explanation is typical of the wording of all of the charges located on the back of the bill. The company needs to go through the bill and clean up the wording so that the consumer can better understand the charges levied on them. In addition to changing the wording, we think they should make move all explanations and charges to the same side of paper, as done by other states on their electric bills (Georgia Power's electric bill for one).

The next recommendation that we will make is about the company clearly showing the whether the bill was standard offer or default. This should be clearly stated on the top of the bill near the balance due, which is outlined with a bright color. Next to this box, there should be a clear and concise explanation of what each type means, and which one is cheaper for the consumer. This goes the same for whether the bill was estimated or actual. It should be listed in its own box outlined with a bright color so that it draws the attention of the consumer and explains that the consumer should call if they do not want the power company to estimate their bill, and it should state that the company will only err on the high side of the amount. Putting these two values in the format that we have listed ensures that the consumer will see them and understand them better, further allowing them to understand the bill.

Now to the charges on the front of the bill; these should be shown with the actual dollar amounts next to them and how the company computes the KWh figure that determines the final balance of the bill. Granted, with all these charges it is going to be difficult to let the average person know what they are being charged for, but just by simply putting dollar signs next to the decimal figures that is the amount of cents of each charge times the KWh used would let the user know that they can add everything up and double check and give themselves piece of mind that they are not being taken advantage of by the electric company.

Finally, the last recommendation that we will make is the location of the due by date on the bill. This is very important because the consumer needs to know when they must make the payment by. It should be located near the amount due, again in its own box that is outlined with a bright color as to draw the consumers' attention to that locale. We feel that with all of these changes mad, the electric company will have many more satisfied customers, and they can dispel the thoughts that the company is just designing the bill the way they do currently to confuse the user and just get their money.

8.4 Goal 3: Device Recommendations

The final recommendation we will introduce in this project is a recommendation for further work on the design of a device to help consumers gauge their usage of electricity in between their power bills. First of all, we uncovered a phenomenon in the literature review whereby daily feedback on power consumption helps consumers to conserve electricity on their own. In keeping with this idea, we decided to create a theoretical design for a device to help keep consumers abreast of their electrical usage.

Our design for this device is based on some central design concepts which serve as the foundations for interface design. The sample screens presented in the results section indicate how the interface for this device might work, and the screens and descriptions of this device outline what the requirements of this device would be. The menu design, external interface, and internal interface have all been at least outlined for the reader.

While we have done a substantial amount of the work in designing the concept and interface for this device, a large amount of work remains to be done to bring this idea to fruition. The actual construction of a device like ours is far out of the scope of this project, but it may fit very well into an ECE or EE MQP. It is therefore our recommendation that the device design we outlined in the results section of our paper be considered for future design work, and possible implementation.

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Apendix A – Survey Information

This appendix contains the forms we handed out for particular surveys. They have been preserved in their original condition with nearly identical formatting.

A.1 Auburn Survey Cover Letter

A.2 Auburn Survey

A.3 Mark Trail Survey Cover Letter

A.4 Mark Trail Survey

Worcester Polytechnic Institute

Seth Chandler
WPI Box 1635
100 Institute Rd.
Worcester, MA 01609

Dear Neighbor,

Some of you may know me, and others may not; my name is Matthew Clark, and I live in the neighborhood at 24 Lorna Dr. I am currently a junior at Worcester Polytechnic Institute in Worcester, Massachusetts. My partners, Seth Chandler, Jason Shook, and Justin Wheeler, are currently juniors at WPI as well. Attached to this letter you will find a short survey my partners and I are doing on electrical conservation.

The survey is part of a larger project on the conservation of electricity in a residential area in conjunction with the Massachusetts Electric Company and my school. The project is one of three main projects that each student must complete for graduation requirements.

Your household is one of a small number of residences which are being asked to contribute some information and opinions for our project. Your household was selected randomly from a list of houses on certain streets in Worcester County. In order for the results of our project to truly represent the thinking of people in our community, it is important that each questionnaire be completed and returned in the envelope provided. The address on the envelope is one of my partners on campus mail boxes; we decided to use this for several reasons, including the reliability of the on campus mail service and its central location in the campus center. Please keep in mind, this data is the most important part of our project, so your cooperation in filling them out is greatly appreciated!

It's also important to remember that this questionnaire is completely anonymous; you are assured of complete confidentiality. The questionnaire has an identification number for mailing purposes only. This is so that we may check your name off the mailing list when your questionnaire is returned. Your name will never be placed on the questionnaire itself.

I would be happy to receive any questions or comments you may have about this study. These questions, comments, or concerns may be written anywhere on the returned survey. Thank you very much for your assistance.

Sincerely,

Matthew D. Clark

Part 1 Mail ID Code: ___ -___

1. Please note how many people live in the house from the selected age groups:

Ages:	Under 10	10 – 25	25 – 35	35 – 50	50 – 65	over 65
	________	________	________	________	________	________

2. Please note the number of people of each gender currently living in the house:

Gender:	Male	Female
	________	________

3. How long have you lived in this house? _______ years

Part 2

1. Do you have electric heat and/or electric space heaters? (Disregard Gas or Oil Heat)

Yes No

2. Do you have air conditioning? Yes No

2b. If yes, is it window, central, or both?

Window Central Both

3. Do you have an electric range/oven? (Disregard Gas Ranges/Ovens)

Electric Range Electric Oven Both No/Different Power

4. Do you have an electric hot water heater? Yes No

5. Do you have a washer and dryer? Yes No

5b. Is the dryer electric or gas? Electric Gas

6. How many refrigerators and freezers do you own? ____ refrigerators ___freezers

7. Do you have a pool or Jacuzzi? Pool Jacuzzi Both Neither

7b. If yes, does it/they run all year? Both Only One Neither

8. Do you have a 'workshop' (i.e. a place for wood or metal working)?

Yes No

Part 3

1. Do you know off the top of your head if your last bill was estimated or read? (Simply yes or no, we just want to know if you remember either way)

Yes No

2. Would you say that you understand your power bill (e.g. which parts can be controlled and which parts cannot?)

Yes No

3. Would you be interested in a guide to help consumers better understand their power bills?

Yes No

4. Would you be interested in a total redesign of the layout of a power bill?

Yes No

Part 4

1. Would you rate yourself as energy conscious? Yes Somewhat No

2. When purchasing new appliances, do you look at the energy consumption or conservation benefits of that appliance?

Yes No

3. Have you taken advantage of offers from Mass Electric such as their 'Energy Wise' program and/or energy audits?

Yes No

4. Do you turn off appliances to save electricity? (e.g. lights, radios, computers, or televisions when they aren't being used?)

Yes Somewhat No

5. Do you know if your house has proper insulation? Yes No

5b. If yes, is the insulation adequate or not?

Yes it's adequate No it's inadequate

6. Would you be interested in a device that would provide feedback on electrical consumption between power bills, to help you gauge how much electricity you use?

Yes No

Dear Neighbor,

Some of you may know me, and others may not; my name is Seth Chandler, and I live in the neighborhood at 195 Mark Trail. I am currently a junior at Worcester Polytechnic Institute in Worcester, Massachusetts. Attached to this note you will find a short survey my partners and I are doing on electrical conservation.

My partners are Jason Shook, of Thomaston, Connecticut, and Matthew Healy, Matthew Clark, and Justin Wheeler, all of Worcester Massachusetts. The survey is part of a larger project on the conservation of electricity in a residential area in conjunction with the Massachusetts Electric Company and my school. The project is one of three main projects that each student must complete for graduation requirements.

My partners and I would greatly appreciate it if you would take five minutes out of your time and fill out the survey, and mail it back to us in Worcester (we've enclosed a stamped self-addressed envelope for that very purpose). The survey data is the most important part of our project, and we would appreciate it if you would help us out with it.

Finally, the survey is completely anonymous, as we will have no idea which envelope is coming from which house, and each question is optional. If you do not want to answer a specific question, for any reason, that is fine. We appreciate your time, and hope to be receiving a survey from you shortly.

Many thanks,

Seth Chandler

Part 1

1. Please note how many people live in the house from the selected age groups:

Under 10	10 – 25	25 – 35	35 – 50	50 – 65	over 65
________	________	________	________	________	________

2. Please note the number of people of each gender currently living in the house:

Male	Female
________	________

3. How long have you lived in this house? ________ years

Part 2

1. Do you have electric heat and/or electric space heaters? (Disregard Gas Heat)

Yes No

2. Do you have air conditioning? Yes No

2b. If yes, is it window, central, or both?

Window Central Both

4. Do you have an electric range/oven? (Disregard Gas Ranges/Ovens)

Electric Range Electric Oven Both

4. Do you have an electric hot water heater? Yes No

5. Do you have a washer and dryer? Yes No

5b. Is the dryer electric or gas? Electric Gas

6. How many refrigerators or freezers do you own? _______

7. Do you have a pool or jacuzzi? Pool Jacuzzi Both

7b. Does it/they run all year? Yes No

8. Do you have a 'workshop' (i.e. a place for wood or metal working)?

Yes No

Part 3

1. Do you know off the top of your head if your last bill was estimated or read? (simply yes or no, we just want to know if you remember either way)

Yes No

2. Would you say that you understand your power bill (e.g. which parts can be controlled and which parts cannot)

Yes No

3. Would you be interested in a guide to help consumers better understand their power bills?

Yes No

4. Would you be interested in a total redesign of the layout of a power bill?

Yes No

Part 4

Would you rate yourself as energy conscious? Yes Somewhat No

When purchasing new appliances, do you look at the energy consumption or conservation benefits of that appliance?

Yes No

Have you taken advantage of offers from Georgia Power such as their 'Good Cents' program and/or energy audits?

Yes No

Do you turn off appliances to save electricity? (e.g. lights, radios, computers, or televisions when they aren't being used?)

Yes No

Do you know if your house has proper insulation? Yes No

Would you be interested in a device that would provide feedback on electrical consumption between power bills, to help you gauge how much electricity you use?

Yes No

Apendix B – Usability Information

B.1 Usability Questions

B.3 Usability Discussion

Usability Questions

Pre test question-Do you pay your power bill currently?

1.) Please locate the amount that you now owe the electric company (this month and any other back charges).
2.) Please locate the due date of this charge.
3.) Is this bill estimated or actual?
4.) How many KWH did you use for this billing period last year?
5.) What month did you use the most KWH last year?
6.) Locate the dollar amount that you are charged for "energy conservation"
7.) Locate the dollar amount that you are charged as a flat rate (you have no control over this charge)
8.) Locate the amount of money that was paid by you last month, and what amount is currently overdue on the bill.
9.) Is this bill standard offer or default service? Do you know what the difference is?

Post test question-What did you find ambiguous on the bill, and what do you think should be changed?

Subject #1

For the first question, the first subject was very quick to answer this question correctly. On the second question, this person saw the date that the account was billed on for that month, but needed some assistance from myself to show them where the due date is. With the third question, the subject answered correctly in 10 seconds, which is fairly quick. On the next question, the subject stuttered a bit and then figured out that the calendar goes from bottom to top through the months, and answered correctly. On the fifth question, the subject easily located this value very quickly. Now with the sixth question, the subject apparently didn't see that there are two pieces of paper stapled together for this bill, but when we showed them the other page, they located the value quickly. With the seventh question, the subject took some time to further analyze the bill, 23 seconds to be exact. The subject had no problem with the eighth question, locating both of the answers in ten seconds, which again is fairly fast. On the ninth and final question, the subject took about 13 seconds here and they didn't have any idea what the difference between the two offers was. Finally, on the pre test question, the subject stated that they do not currently pay an electric bill, but that they would in the future, and on the post test question the person said that they were very intimidated by the layout of the bill, and added that they thought that the electric company is not doing all that they can for the consumer to understand the bill.

Subject #2

For the first question, this subject was very quick to answer this question correctly. On question two, as with question one, the subject located the pay by date with ease. After we asked them the third question, the subject asked me what we meant by estimated or actual, and then it took 21 seconds to find the correct answer. On the fourth question, the subject was very confused about the calendar and after about half a minute we had to show them how it was set up, and then still answered incorrectly. Now on to the fifth question; here the subject pointed to the highest number in the list, but then said the wrong month that corresponded to it. (It was M for March, but the subject could not understand the calendar layout, and thought that it was May) With the sixth question, the subject knew to flip the page of the bill and was very quick to answer the question correctly. On the seventh question, they knew to look at the other page of the bill and answered very quickly. On the eighth question, the subject had no problems here; they answered what we asked very in practically no time at all. With the final question of the test, the subject needed my help again, we ended up pointing to where it was and they had no clue what the difference was. Finally, on the pre test question, the subject stated that they do not currently pay an electric bill, but that they would in the future, and on the post test question, the person had great difficulty with understanding the way that the calendar was laid out, and they had no idea what the difference was between the two types of service offered by the electric company. (Standard and default)

Subject #3

For the first question, this subject was very quick to answer this question correctly. On question two, as with question one, the subject located the pay by date with ease. Here on the third question, we was asked what the difference was but we needed to say that it doesn't matter, because knowing that doesn't help you find it, but after about half a minute they found it. On the fourth question, the subject understood the calendar quickly, and pointed to the correct value. On the fifth question the subject found the correct month with no problems, but then asked me what the KWh means. On the sixth question, the subject flipped the page, and located the value quickly, and then asked me what the electric company means by this charge. With the seventh question, the subject found this value quickly and wanted to know why for and why if they don't use as much electricity, the charge is still the same for everyone. On the eighth question, the subject took about 11 seconds to answer correctly with no help. On the final question, the subject told me the correct answer very fast, and did not know the difference, then flipped it over, still couldn't find it (it is not on there) and then they began to get a little mad about why the company doesn't tell you what they are. Finally, on the pre test question, the subject stated that they do not currently pay an electric bill, but that they would in the future, and on the post test question, the subject complained that the electric company should tell the buyer what the difference is between standard and default, and what all the other charges are. We showed him the back, but he thought that everything was worded quite poorly.

Subject #4

For the first question, this subject was very quick to answer this question correctly. On the second question, the subject gave this answer to me very quickly, and did not require any assistance. While doing the third question, the subject asked me what the difference was, and found this quite quickly again. Now on to the fourth question, the subject had no idea how the calendar works, but then when we explained it to them, they had no troubles finding the correct month. On the fifth question, they pointed to the largest number, and then it looked as if they guessed the month correctly, and then asked me what KWh means. With the sixth question, the subject flipped the bill over with no problems, and then located the amount, and was very inquisitive as to what that charges means. On the seventh question, the subject found the amount with little trouble, but wanted to know what the flat charge was actually for. On the eighth question, the subject found these values with some difficulty. (About 17 seconds for both) With the final question, the subject saw the correct answer and pointed to it within 5 seconds, but then asked what the difference is and why it is not explained on the back of the on the back of the bill. Finally on the pre test question, the subject stated that they do not pay a power bill currently, but they will have to do so in the future. On the post test question, the person had some problems with the calendar, more specifically why it was formatted like it was (upside down) and why the wording was so poor on the explanations of the charges on the bill.

Subject #5

For the first question, this subject was very quick to answer this question correctly. On the second question, the person saw the date that the account was billed on for that month, but needed some assistance from myself to show them where the due date is. With the third question, they saw the correct answer and answered quickly, but again we was asked what the difference is, and they were shocked to hear that the company likes to estimate most of the bills, and that you have to request an actual reading. On the fourth question, the subject had a problem with the calendar. After we told them that it was upside down, then they got it. Now that they knew how the calendar was set up from the fourth question, they answered the fifth question correctly, but then they asked me to show them how the company computes KWh. On the sixth question, the subject flipped the bill over with no problem, and found the charge, but doesn't know what the charge means, and they started to look at all of the wording on the back of the bill, and then they said that the wording could be much clearer on the back. On the seventh question, the subject had some trouble (took 16 seconds) but founds it and then goes to the back to see what that is on there for, and became a little mad that the consumer has no control over it. On the eighth question, this person found both of the figures with no difficulty. On the final question of the test, the subject took some time, and looked over the bill again, and found the correct answer, but then looked at the back and couldn't find the explanation on this topic. Finally on the pre test question, the subject stated that they do not pay a power bill currently, but they will have to do so in the future. On the post test question, the subject complained about the wording being confusing, and why they do not tell you the difference between standard offer service and default service.

Subject #6

For the first question, this subject was very quick to answer this question correctly. On the second question, the subject gave this answer to me very quickly, and did not require any assistance. With the third question, the subject had no problem with finding it, but they didn't know what the difference was. Again here on the fourth question, another subject had a problem with the way that the calendar is laid out. We needed to explain to them that it was upside down, and then they got it right. The subject had no problem with the fifth question because we showed them how the calendar was laid out in the last question. On the sixth question, the subject flipped the bill over, but still couldn't locate the value within 20 seconds. The subject did not understand what the charge is for, and asked me why the electric company is charging customers to conserve electricity. On the seventh question, the subject found this with no problem, but didn't understand the charge ever after reading the explanation. On the eighth question, the subject took about ten seconds to get both of them correct with no assistance from myself. On the ninth question, the subject found the correct answer, but then they didn't understand the explanation because it is not on the bill. Finally on the pre test question, the person does not pay an electric bill, and on the post test question, the subject thought that the electric company should word their explanations better, and that they should tell you the difference between standard and default, and between estimated and actual.

Subject #7

For the first question, this subject was very quick to answer this question correctly. On the second question, the subject gave this answer to me very quickly, and did not require any assistance. On the third question, the subject got this answer correct very quickly, but didn't know what the difference was. With the fourth question, the subject couldn't figure out the calendar, and then we had to show them how it is laid out, and then they answered correctly. On the fifth question, the subject got this with no problems after understanding the calendar. With the sixth question, the subject found the correct answer in 17 seconds, but didn't understand the charge, and didn't bother to look at the explanations on the back on the bill. On the seventh question, the subject found this quickly, but didn't understand this charge, and started to read the explanations. Then they said that the wording could be better, and that they thought that the company was just trying to confuse the customer, so that they won't even bother to read the back. On the eighth question, the subject had some trouble with this, but found the correct values for both in about 25 seconds total. With the final question, the subject couldn't find it, and we had to show them. This subject became very agitated with the wording and the bill in general and again thought that the electric company was just doing this to confuse the customers. Finally on the pre test question, the person does not pay an electric bill, and on the post test question, the subject thought that the whole bill in general was ambiguous, and says that the bill should be worded much more clearly, and the calendar should be easier to understand.

Apendix C – Pamphlet Information

C.1 List of energy saving tips to include in a pamphlet

C.2 Description of pamphlet information

C.3 A rough design of the proposed pamphlet

Energy Saving Tips

Refrigerators with bottom freezers are the most efficient, followed by models with top freezer, and side-by-side models are the least efficient.
Through the door icemakers and water dispensers waste energy.
Manual defrost refrigerators can save a lot of energy if the owner remembers to defrost them on a regular basis.
The coils on the back of the refrigerator should be brushed or vacuumed on a regular basis.
The refrigerator should be kept between 35-38° F.
Energy Star rated refrigerators consume much less energy than regular models.

Chest freezers are more efficient than upright models.
Manual defrost models consume much less energy than automatic defrost models if the owner remembers to periodically defrost them.
Freezers should be kept at 0° F.

Buy a clothes dryer with a high energy factor and a moisture sensing setting.

Buy a clothes washer with a high energy factor, Energy Star rated washers have an EF of 2.5 or higher.
Horizontal axis washers are much more efficient than top loading washers.
When possible, wash clothes in cold water.

Buy a self-cleaning oven to save energy, but use the self cleaning feature a maximum of once per month.
Use the self-cleaning feature immediately after cooking, so the oven is already hot.
Halogen and induction cook-top elements will save energy over solid disk elements and radiant elements under glass.
Use flat-bottomed pans that match the size of the cook-top element.
Preheat the oven only when necessary.
Use glass or ceramic pans and pressure cookers to save energy.
Do not open the oven door to check the food.

Buy a dishwasher with an energy factor of 0.58 or higher.
Use the "light wash" or "energy saving" wash cycles and the air-dry option as much as possible.
If the dishwasher does not have an air-dry option just stop the dishwasher after the wash cycle and open the door to let the dishes air-dry.
Do not pre-rinse dishes before putting them in the dishwasher, just scrape off the food.
Fill the dishwasher to capacity for each wash.

Buy a central A/C with a SEER (seasonal energy efficiency ratio) of 12 or higher.
Keep indoor coils clean.
Do not use bath and kitchen fans, cook, or use the dishwasher while the A/C is in use.
The thermostat should be set at 78° F or higher.

Windows on east and west sides of the house should be shaded.

Make sure that your room A/C unit is properly sized for the room.
Buy an A/C with a high EER (energy efficiency ratio) of at least 10.
Clean and replace the air filters on a regular basis.
Keep drainage channels clean at all time.
Try to place the A/C unit in the shade.
Use interior fans to replace or assist the room A/C unit.
Do not place lamps or televisions near the thermostat for the A/C unit.

Buy an electric space-heating furnace with a high AFUE (annual fuel utilization efficiency) rating of 95% or higher.
When buying a space-heating furnace, opt for a sealed combustion heater rather than a non-sealed one.
Shades should be used on all south, east and west facing windows. They should be open during the day and closed at night.

Buy a water heater with a high energy factor (EF) of 0.8 or higher.
Buy a water heater with the correct FHR (first-hour rating), which is the amount of hot water the water heater can produce during a busy hour. The FHR should be matched to the peak-hour demand for the given house.
Water heaters and piping should be installed in heated areas of the house and pipe lengths should be minimized.
Use low-flow faucets and showerheads and fix all water leaks.
The thermostat on the water heater should be set to 120° F.
Install a timer on the water heater to shut it off at night.
Take showers instead of baths.

Our project goal to help consumers conserve electricity and save money has led us to write up a pamphlet of energy saving tips on appliance usage. Our survey has shown that consumers would read and use such a guide to cut energy costs in their homes. All of the information on the pamphlet was taken from our literature review section. The pamphlet is split up into two categories: tips for buying an appliance and tips for using an appliance.

When buying an appliance the consumer must check the necessary energy ratings on each appliance to compare different models. For all appliances that have efficiency ratings, their information is listed on the Energy Guide Label. The Energy Guide Label is a bright yellow tag or sticker with black lettering that is required to be present on most types of appliances. It lists the specific efficiency ratings for the particular appliance and can be compared with the ratings on all other models of the same appliance, regardless of the manufacturer.

Energy Star rated appliances are those that far exceed the government efficiency standards. Energy Star ratings are given to only the most efficient appliances and should be purchased over a regular appliance if it is possible.

If the consumer already owns the appliance and wishes to conserve energy without purchasing a new one the second section of tips will assist them. Most consumers will not be able to utilize all the tips listed but following as many as possible will help them consume the minimum amount of energy while maintaining their current lifestyle.

Not all of the possible energy saving tips are listed on the pamphlet. This is done to save space and make it easier for the consumer to read. Explanations of each tip are also not provided on the pamphlet for the same reasons of space and readability.

Side-by-side refrigerator are the least efficient because every time the doors are opened all of the cold air falls downward and empties out of the refrigerated compartments. With top or bottom freezer models there is les vertical area to cool off and therefore they consume less energy. For the same reason upright freezers are less efficient than chest freezers. When an upright freezer is opened all the cold air sills out of the freezer onto the floor, but when a chest freezer is opened the cold air stays inside the freezer.

Through the door icemakers and water dispensers allow for areas of less insulation in the refrigerator door. This results in cold air escaping from the refrigerator due to leaks and heat transfer through areas of less insulation. Refrigerators and freezers should not be kept at too cold a temperature because it will cause the motor and compressor, which keep the refrigerator cold, to work too hard. The coils on the refrigerator should be kept clean to ensure the proper heat transfer rates that the refrigerator was built for.

Manual defrost refrigerators and freezers save more energy that automatic defrost models. The automatic defrost models may use the defrost function more often than is necessary and waste energy.

The majority of energy used by clothes washers goes towards heating of water. Therefore the less water used the better the efficiency. That is why horizontal axis clothes washers are more efficient than top-loading models. The horizontal axis washers do not fill completely with water, the bottom of the washer is filled with water and the clothes are tumbled around inside, in and out of the water. Another way to save energy with a clothes washer is to wash clothes in cold water. By doing this, no energy has to be spent in heating the water.

Self-cleaning ovens have more insulation in them and better door seals so they are more efficient for normal operation than regular ovens, but if the self-cleaning feature is used more than once per month, the energy savings get all used up. Also, the self-cleaning feature should be used right after cooking because the oven will already be hot.

Pot and pan size should be matched to the sizes of the electric cook top. If the pan is too small heat will rise past the pan and be wasted and if the pan is too big it will take more energy than necessary to heat up the pan. Also the use of glass or ceramic pans can increase efficiency due to the way that those materials conduct heat better than aluminum or other metals. Pressure cookers also save energy because it takes much less heat to cook the same foods under pressure.

As with refrigerators and freezers, opening the door lets the air out of the appliance. Every time the oven door is opened the temperature inside drops by about 25° F (DOE, 2001).

Using an energy saving wash cycle on a dishwasher saves energy by using less water than on the regular cycle. The heating of the water is where the majority of energy is spent in a dishwasher. Also, the drying cycle uses a lot of energy so by air-drying dishes that energy is saved.

Dishes should not have to be pre-rinsed before being put in the dishwasher. The energy used in pre-rinsing the dishes is unnecessary and wastes energy through the hot water heater and water pump. The dishwasher should be filled up all the way for each wash because the dishwasher will use the same amount of water for each cycle, regardless of the amount of dishes in it.

Using bath and kitchen fans wastes energy by pulling heated or cooled air out of the house. If the A/C or the heater is running the bathroom and kitchen fans should be used sparingly.

A/C units should have clean filters at all times so the motor does not have to work extra hard to pull air through the appliance. Also, placing a room A/C in the shade will keep the motor from overheating and working too hard.

Window shades must be used along with A/C and heat use throughout the year. The shades on east, south, and west sides should be drawn at all times except during the day when the heater is on. This allows heat from the sun to enter the house and assist the heater while the shades are up, and while they are down they help keep hot or cool air inside the house.

In some cases room fans can be substituted for A/C units and a lot of energy can be saved. Also, if lamps or televisions are placed near a thermostat it will seem like it is hotter in the room than it really is and the A/C will run for longer than it should.

Low-flow faucets and showerheads save energy by using less water than normal ones. Installing a timer on the water heater to shut it off at night will stop it from cycling on during hours when hot water is not needed. Taking a shower instead of a bath uses much less water and subsequently saves energy in the heating of water and in running the water pump.

Energy Saving Tips

For Appliances

A Common sense guide to appliance purchase and usage

Tips for buying a new appliance

- Energy Star rated appliances consume much less energy than regular models and will save money in the long run.

- Refrigerators with bottom freezers are the most efficient, followed by models with top freezer, and side-by-side models are the least efficient. Also, chest freezers are more efficient than upright models.

- Manual defrost refrigerators and freezers save a lot of energy if the owner remembers to defrost them on a regular basis.

- Look for clothes washers and dryers with high energy factors (EF), Energy Star rated washers have an EF of 2.5 or higher

- Look for a clothes dryer with a moisture sensing setting.

- Horizontal axis washers are much more efficient than top loading washers.

- Look for a self-cleaning oven to save energy, but use the self-cleaning feature a maximum of once per month.

- Halogen and induction cook-top elements will save energy over solid disk elements and radiant elements under glass.

- Look for a dishwasher with an energy factor of 0.58 or higher.

- Look for a central A/C with a SEER (seasonal energy efficiency ratio) of 12 or higher, and keep the indoor coils clean.

- Make sure that your room A/C unit is properly sized for the room, and look for one with a high EER (energy efficiency ratio) of at least 10.

- Look for an electric space-heating furnace with a high AFUE (annual fuel utilization efficiency) rating of 95% or higher. When buying a space-heating furnace, opt for a sealed combustion heater rather than a non-sealed one.

- Look for a water heater with a high energy factor (EF) of 0.8 or higher, and one with the correct FHR (first-hour rating). The FHR is the amount of hot water the water heater can produce during a busy hour, and should be matched to the peak-hour demand for the given house.

Tips for using your appliances

- Refrigerators should be kept between 35-38° F, and freezers should be kept at 0° F. The coils on the back of the refrigerator should be brushed or vacuumed on a regular basis.

- When possible, wash clothes in cold water.

- Use the "light wash" or "energy saving" wash cycles and the air-dry option as much as possible. If your dishwasher does not have an air-dry option just stop the dishwasher after the wash cycle and open the door to let the dishes air-dry.

- Do not pre-rinse dishes before putting them in the dishwasher, just scrape off the food, and fill the dishwasher to capacity for each wash.

- Do not use bath and kitchen fans, cook, or use the dishwasher while the A/C is in use, and set the thermostat at 78° F or higher.

- While cooling the house, windows on east and west sides should be shaded.

- Clean and replace the air filters on a regular basis, and keep drainage channels clean at all time.

- Try to place the A/C unit in the shade.

- Use interior fans to replace or assist the room A/C unit.

- Do not place lamps or televisions near the thermostat for the A/C unit.

- While heating the house, shades should be used on all south, east and west facing windows. They should be open during the day and closed at night.

- Water heaters and piping should be installed in heated areas of the house and pipe lengths should be minimized.

- Use low-flow faucets and showerheads and fix all water leaks.

- The thermostat on the water heater should be set to 120° F.

- Install a timer on the water heater to shut it off at night.

- Take showers instead of baths.

- Use the self-cleaning feature on your oven immediately after cooking, so the oven is already hot.

- Use flat-bottomed pans that match the size of the cook-top element, and use glass or ceramic pans and pressure cookers to save energy.

- Preheat the oven only when necessary, and don't open the oven door to check the food before it is ready.