Puerto Rico Residential Energy Study

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Abstract

The growing dependency on fossil fuels and the high costs of electricity generation in Puerto Rico have caused the Puerto Rico Energy Affairs Administration to examine measures to conserve energy in residences. The goal of this project was to assess residential energy characteristics and develop residential energy efficiency guidelines to aid in creating a home energy rating system for Puerto Rico. Major objectives included determining current energy use in Puerto Rican residences, through implementation of online surveys and walk-through energy audits, and developing a list of energy conservation recommendations based on the collected data. The results gathered in this study were used to develop recommendations for both the AAE and future project teams for further studies. These recommendations include alterations to the survey and audit forms as well additional analysis methods. The project team believes that the data collected in this study will prove valuable for the development of a home energy rating system in Puerto Rico.

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Executive Summary

The global economy has been directly impacted by the growing dependency on fossil fuels. The high cost of these fuels has led to increased energy costs. Puerto Rico needs more efficient energy consumption, which may prove to be crucial to the future economic success of the island. Due to its heavy reliance on fossil fuels, Puerto Rico is experiencing significant issues with its energy consumption and is in search for a method in which to conserve energy. It is important for the island to adopt a home energy rating system in order to address the energy consumption problems within the residences of Puerto Rico.

The goal of the project was to assess residential energy characteristics and develop residential energy efficiency guidelines to aid in creating a home energy rating system for Puerto Rico. Major objectives included:

- Determining current energy use in Puerto Rican residences
- Developing a list of energy conservation recommendations for the Puerto Rico Energy Affairs Administration (AAE) and citizens of Puerto Rico

These objectives were completed by implementation and analysis of an online survey sent to a sample population and walk-through audits performed in preselected residences.

The online survey was developed in an effort to gain an understanding of residence characteristics, home energy consumption, as well as the general awareness and implementation of energy conservation techniques. Questions were designed to investigate the quantity and type of common household appliances and how often the appliances were used. For example, the type and number of air conditioners in a home was an important characteristic that the group chose to investigate in the survey. To gauge awareness of energy conservation techniques a multi-answer survey question with many different energy saving techniques was utilized. The survey was emailed through our liaison Alexis Miranda of the AAE to two mailing lists, approximately 14,000 professionals in total, from The Manufacturer's Association of Puerto Rico and The College of Engineers & Surveyors of Puerto Rico.

The survey was constructed in an online format using Google Documents. Google Documents allows the online survey to be easily formatted and distributed through email with the use of a hyperlink. Survey response data was collected in a spreadsheet and saved on a Google server where it was easily downloaded into a Microsoft Excel file. The survey was beta tested within the AAE and checked for problems with the Google Documents application before being sent out to the two email aliases. Questions were added or subtracted based upon recommendations from contacts at the AAE. The Spanish version of the survey was translated by an employee of the AAE based upon the revised version of the English survey. The group received approximately 900 survey results, which were analyzed and processed for energy consumption trends.

The walk-through audit was developed as an additional means to gather data on typical energy use for residences. It was developed in reference to the RESNET Comprehensive Home Assessment and included an interview portion as well as an in-depth examination of both structural components of the residence and appliance use and condition. Due to time, resource, and experience limitations, the audit form went through many revisions before the final audit form used in this study was developed. The team also beta tested the audit and found that it contained too much information, which was either not relevant to our project or not viable to assess as students performing research. After the beta test, the audit went through a substantial revision to make it more concise and relevant to our study and was renamed "energy walk-through" at the request of the AAE. This was done so that interested volunteers would not be expecting a full professional audit if the team examined their home. Five walk-through audits were performed and the insights developed during this process may be useful for future studies.

The thorough analysis of the collected survey and audit data was a key component to the successful completion of this project. The survey data was organized using two methods developed by the group members and AAE personnel: one method organized the response data according to occupancy size and the second approach organized the total data from all of the responses. Separating the data by occupancy groups benefited the analysis in that it allowed for the investigation of whether certain energy use characteristics were dependent upon the number of residents within a household. The results and analysis for the combined responses were used as the typical residential energy characteristics of a Puerto Rican home, based on the data from the surveyed population. Due to the potential bias with the surveyed population, it should be noted that these characteristics may not be representative of the residences on the entire island. The survey responses came from government personnel, industrial workers, and engineers.

The analysis of the survey data allowed the group to discern certain trends about residential energy. These trends were related to household information, current energy use, energy conservation techniques, and energy consumption and bills. Due to the small number of audits that were performed, it was not possible to establish any trends from this data; however, the audit results supported the data found with the online surveys, as well as providing some additional insights. Some of the general trends shown within the survey data were reinforced by the audits and are highlighted below.

- Typical residence size for the survey population is 1,000 to 2,000 square feet.
- A majority of the residences were constructed between 1990 and 2010.
- The number of air conditioners per residence is generally occupancy dependent. Split unit air conditioners are the most common types of cooling systems within the residences.
- A majority of the residences consist of electric laundry dryers and electric water heaters.
- A significant portion of the survey population is aware of ENERGY STAR and implements energy efficiency techniques within their households.
- Typical monthly energy consumption of the survey population is 300 to 800 kilowatt-hours and the average monthly energy bill is $80 to $200.

The group developed residential energy conservation techniques based on areas of potential improvement that were identified through analysis of the survey and audit results. Residential energy conservation techniques for the AAE and residents of Puerto Rico are listed below.

- Renovate homes, particularly those built prior to 1990, with additional energy efficient appliances and construction.
- Decrease residential laundry machine and dryer use by urging residence to do less loads of laundry, use communal Laundromats, and air dry clothing when possible.

- Reduce the time of air conditioner use, as well as other household appliances, by setting timers that control the duration of use.
- Replace traditional incandescent light bulbs with energy efficient compact fluorescent light bulbs.
- Turn off electric water heaters when they are not in use. Invest in solar water heaters which are more energy efficient and gaining popularity on the island of Puerto Rico.
- Increase the number of ENERGY STAR appliances used within residences.
- Unplug household appliances that are not in use.

Final deliverables for the project were presented to the AAE in a final report and presentation. These deliverables consisted of the current residential energy characteristics of the survey population and a listing of identified energy conservation techniques. Characteristics of the typical Puerto Rican residence were based on results from the survey population and audited residences. It is understood that this population is likely to be unrepresentative of the population of Puerto Rico as a whole.

While working on this project, the group learned a significant amount about the energy problem Puerto Rico is facing and learned lessons about teamwork and how to deal with the issues that are associated with large group projects. The project also gave the group an opportunity to work in a government agency and practice electronic surveying and walk-through auditing. It is the hope of the group that the data acquired through this study will prove to be important in the AAE's development of a home energy rating system and that the recommendations for future work will be beneficial in the continuation of this research. The group feels that the recommendations provided to the AAE regarding energy conservation methods will be valuable in helping the residents of Puerto Rico lower their overall energy consumption.

Chapter 1: Introduction

The growing dependency on fossil fuels has had detrimental effects on the global economy and raised concern with the efficiency of energy use. High energy costs and the threat of a potential collapse of the economy have demanded an increased awareness for energy conservation. On the island of Puerto Rico, the need for efficient energy consumption is magnified due to the reliance on foreign oil for the production of power. The dependence on foreign oil, along with the energy distribution monopoly held by the Puerto Rico Electric Power Authority (PREPA), have created increased electricity costs for Puerto Ricans (L.M. Bernal-Jimenez, personal communication, Dec. 14, 2009). Consequently, guidelines to assess current energy use and promote energy conservation may greatly benefit the entire island.

This project was sponsored by the Puerto Rico Energy Affairs Administration, known as the Administración de Asuntos Energéticos (AAE) in Spanish, which works in conjunction with many government sectors, such as the Environmental Protection Agency (EPA) and the Department of Energy (DOE), to address energy consumption. The AAE is an important organization that takes on many roles in supporting energy efficiency in Puerto Rico. Responsibilities, among others, consist of administering and enforcing energy policy and developing conservation strategies on the island. Some of the major services of the Puerto Rico Energy Affairs Administration include: providing technical advice to businesses for conservation and efficient energy use; distributing energy related information through regular publications; educational programs regarding energy efficient practices; and promoting alternative and renewable energy projects (www.aae.gobierno.pr, 2010).

The Puerto Rico Energy Affairs Administration is located in the city of San Juan. In addition to San Juan, this study focused on a number of other regions dispersed around the island. A majority of these areas consisted of high population densities. As of July of 2009, the population of Puerto Rico was approximately 3.97 million people, which correlates into a population density of about 1,100 people per square mile (www.topuertorico.org, 2010). With such a large population density, reductions in energy use on the individual level could yield substantial benefits toward lowering overall residential energy consumption.

The AAE assigned the project group to investigate characteristics of current residential energy use and conservation techniques in Puerto Rico. The underlying issue that was addressed in this study is the lack of any existing home energy rating system for Puerto Rico. The findings may directly impact the welfare of Puerto Rico's residents as recent soaring energy costs are causing economic hardships, such as problems paying electric bills. Currently, residential energy efficiency issues in Puerto Rico appear to stem from the overuse of everyday household items, such as air conditioners, computers, and kitchen appliances. This project investigated the extent of energy use and conservation techniques within residences. Energy conservation is important toward ensuring that future populations are not negatively impacted by the current generation's overconsumption of natural resources.

The goal of the project was to assess residential energy characteristics and develop residential energy efficiency guidelines to aid in creating a home energy rating system for Puerto Rico. Objectives that were met to achieve this goal included: determining current energy use in Puerto Rican homes, through implementation of online surveys and walk-through energy audits, and developing a list of energy conservation recommendations for the AAE and citizens of Puerto Rico. Final deliverables that were presented to the AAE consisted of the results of the energy survey and five walk-through audits, along with a list of energy conservation techniques. The outcomes of this project were designed for the Puerto Rico Energy Affairs Administration to use in developing a home energy rating system. The study should also provide residents with knowledge of how to implement additional energy efficiency practices in their households. In the following chapters, the group will present pertinent background research, the methodology that was followed, the results of the study that achieved the outlined goal and objectives, and recommendations for energy conservation and future work.

Chapter 2: Background & Literature Review

The island of Puerto Rico currently lacks any existing home energy rating system. Due to this absence, the island experiences numerous economic hardships associated with energy use and its dependence on imported foreign oil. The Puerto Rico Energy Affairs Administration (AAE) requested that the project group analyze residential energy use and create a set of guidelines to aid in the development of an energy efficiency rating system. The scope of work for the project includes determining current energy use and proposing practical solutions to enhance the energy efficiency of residences.

The review of relevant literature presented in this chapter provided a general understanding of energy use and consumption patterns, benefits of energy simulations, existing energy conservation guidelines (i.e. energy codes and rating systems), techniques for energy use assessments, the feasibility of alternative energy and energy saving practices, and pertinent case studies. This information was critical for the successful completion of this project.

2.1 Energy Generation, Uses, and Simulations

Puerto Rico relies almost completely on imported fuel for energy generation. It is necessary to understand how electricity is consumed, especially within homes, so that practical energy conservation techniques can be put in place. Accurate energy simulations are a useful tool in predicting energy consumption and the potential impact of energy efficiency strategies. The development of energy simulations will be a key tool for the AAE in an effort to conserve energy in Puerto Rico.

2.1.1 Dependency on Fossil Fuels

Like most island regions, Puerto Rico, has a dependency on fossil fuels for the generation of energy (Weisser, 2004). Over the past decade, oil prices have peaked due to global politics and increased demand. The variability of oil prices directly impacts the cost of energy to the consumer on islands like Puerto Rico. Currently, Puerto Rico's energy generation consists on a 99% dependency on fossil fuel where 65% comes from oil and its derivatives, 17% natural gas, and 15% coal. The remaining 1% comes from hydro plants and distributed generation units, mainly solar photovoltaic systems (A. Miranda, personal communication, May 3, 2010). There is an economic risk associated with a high dependency on fossil fuels. As Daniel Weisser notes,

> ...a sharp increase in the price of oil can cause severe macroeconomic consequences… [it] might also be deflationary, reducing demand for goods and services, and thereby causing unemployment. A consistent means of affordable energy production is a crucial ingredient to stimulate a growing economy (Weisser, 2004).

The cost of fossil fuels greatly varies with changes in market conditions. Energy production rates from various generation sources can be seen below in *Table 1* from the United States Energy Information Administration.

Table 1: Energy Production Rates from Various Generation Sources in Mills ($0.001) per Kilowatt hour (Source: The United States Energy Information Administration, 2008)

Plant Type	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997
Operation												
Nuclear	9.68	9.21	8.95	8.63	8.30	8.86	8.54	8.30	8.43	8.95	9.98	10.83
Fossil Steam	3.65	3.49	3.24	2.97	2.97	2.50	2.59	2.41	2.26	2.24	2.17	2.22
Hydroelectric[1]	5.78	5.44	3.76	3.95	3.95	3.47	3.71	4.27	3.52	3.35	3.09	2.65
Gas Turbine and Small Scale[2]	2.98	2.89	2.99	3.00	3.00	2.76	2.72	3.15	4.08	4.93	3.81	4.36
Maintenance												
Nuclear	6.20	5.79	5.69	5.27	5.27	5.23	5.04	5.02	4.96	5.01	5.77	6.73
Fossil Steam	3.59	3.37	3.19	2.98	2.98	2.72	2.67	2.61	2.42	2.46	2.41	2.42
Hydroelectric[1]	3.89	3.87	2.70	2.73	2.73	2.32	2.62	2.89	2.22	2.03	1.58	1.98
Gas Turbine and Small Scale[2]	2.72	2.42	2.16	1.89	1.89	2.26	2.38	3.33	3.26	4.78	3.42	3.33
Fuel												
Nuclear	5.29	4.99	4.85	4.63	4.63	4.60	4.60	4.67	4.90	5.16	5.39	5.41
Fossil Steam	28.43	23.88	23.09	21.69	21.69	17.29	16.09	18.15	17.73	15.50	15.86	16.73
Hydroelectric[1]	--	--	--	--	--	--	--	--	--	--	--	--
Gas Turbine and Small Scale[2]	64.23	58.75	53.89	55.52	55.52	43.89	31.84	43.55	41.76	27.95	22.85	24.71
Total												
Nuclear	21.16	20.00	19.49	18.53	18.53	18.69	18.18	17.99	18.29	19.12	21.13	22.96
Fossil Steam	35.67	30.74	29.52	27.64	27.64	22.51	21.36	23.17	22.41	20.20	20.43	21.38
Hydroelectric[1]	9.67	9.32	6.46	6.68	6.68	5.79	6.33	7.16	5.74	5.38	4.67	4.64
Gas Turbine and Small Scale[2]	69.93	64.06	59.04	60.41	60.41	48.91	36.94	50.03	49.09	37.66	30.08	32.41

Changes in energy infrastructure are expensive long-term projects that can reduce costs to the consumer over time. Efforts to make changes in legislative policies and efforts to conserve power can more rapidly reduce the financial burden on the consumer; a notable reduction in cost can be seen almost immediately in electrical bills.

2.1.2 Household Energy Use

Energy is used for a multitude of activities in any given Puerto Rican household. To gain a greater understanding of the different economic classes within Puerto Rico, please refer to Appendix A. Since Puerto Rico consists of a tropical climate, a significant portion of energy use comes from the cooling of interior spaces. Almost 24% of home energy use in a tropical climate is attributed to air conditioning (www.energystar.gov, 2009). Other appliances, such as refrigerators, washing machines and dryers, and computers also consume large amounts of electricity. For example, a refrigerator uses approximately five-times the energy of a typical television (Department of Energy, 2008). An average house in the United States uses 11,000-kilowatt hours (kWh) of energy per year at a rate of $0.09 per kWh (Department of Energy, 2008). Electricity in Puerto Rico averages $0.20-0.25 per kWh (A. Miranda, personal communication, March 17, 2010), which means that annual energy expenditures are relatively close in actual dollars to the average U.S. household annual energy expenditure. The group expected that the Puerto Rican residences would have larger monthly energy bills than the continental United States due to this significant difference in the cost of electricity.

Space Cooling

Due to Puerto Rico's location in the tropics, the cooling of a residence, also known as space cooling, is a common source of energy consumption. Most wall-mounted air conditioners are designed to cool single rooms. The energy required to cool a room depends on the square footage; air conditioners are manufactured over a range of power ratings that correspond to different sized rooms. ENERGY STAR, a sector of the U.S. Department of Energy, demonstrates the correlation between square footage and power required for such an application. To be recognized as an ENERGY STAR air conditioner, the unit must be 7% more efficient than the average (www.energystar.gov, 2009). Updating the efficiency of major household energy consumers, such as an air conditioning unit, is a particularly viable means of reducing total household energy use (see *Table 2*).

Table 2: Square Footage and Required Air Conditioner Capacity (Source: energystar.gov, 2009).

Area To Be Cooled (square feet)	Capacity Needed (BTUs per hour)
100 to 150	5,000
150 to 250	6,000
250 to 300	7,000
300 to 350	8,000
350 to 400	9,000
400 to 450	10,000
450 to 550	12,000
550 to 700	14,000
700 to 1,000	18,000
1,000 to 1,200	21,000
1,200 to 1,400	23,000
1,400 to 1,500	24,000
1,500 to 2,000	30,000
2,000 to 2,500	34,000

3. Make any adjustments for the following circumstances:
   - If the room is heavily shaded, reduce capacity by 10 percent.
   - If the room is very sunny, increase capacity by 10 percent.
   - If more than two people regularly occupy the room, add 600 BTUs for each additional person.
   - If the unit is used in a kitchen, increase capacity by 4,000 BTUs.
   - Consider where you install the unit. If you are mounting an air conditioner near the corner of a room, look for a unit that can send the airflow in the right direction.

Cooling Efficiently

Similar to home heating in higher latitudes, there are many simple ways to increase cooling efficiency in tropical locations. Cleaning the coils of a dirty air conditioner can greatly improve its performance, thus requiring less energy to effectively cool a room or dwelling. In sunny climates, window curtains are an effective means of blocking heat from entering a home as the sun's radiation, which is a major source of internal warming. In addition, partitioning rooms with curtains lowers the temperature of certain, more frequently inhabited areas of a home without wasting energy cooling unused spaces. By using these straightforward methods, the load placed on air conditioning units can be reduced, which in turn lowers the total energy consumption (ENERGY STAR, 2009).

Appliances

Air conditioners are not the only major source of energy use in homes. An average refrigerator uses over 1,000 kWh of electricity in just one year, while a computer consumes a little over 500 kWh in the same period (Department of Energy, 2008). Another large contributor to household energy use is water heating. According to the U. S. Department of Energy, 14-25% of energy consumed is due to water heaters (www.energysavers.gov, 2009). Presently, solar water heaters are fairly common and could be very practical for applications in Puerto Rico.

Lighting accounts for 15% of electricity use within an average home (www.energysavers.gov, 2009). Fluorescent lighting has become very popular as a simple way to reduce utility bills. Fluorescent bulbs use 25-35% less electricity than equivalent traditional incandescent bulbs and last ten times longer; reducing costs in multiple ways (www.energysavers.gov, 2009). Putting timers on lights is an effective way to prevent over consumption. Furthermore, strategic placement of lighting fixtures often improves the efficiency of a home. A table ranking the energy consumption of different household appliances can be found in Appendix A.2.

2.1.3 Energy Simulations

Energy simulations are useful tools to analyze the influence that a variety of variables have on the energy consumption of a municipality, county, state, or region. Such variables include: weather, climate, construction methods, dwelling characteristics, income, household size, and type and number of appliances. There are a few different methods of creating energy simulations. The "top-down" method forecasts energy consumption based upon large-scale sampling of residential regions as a whole. Inversely, the "bottom-up" method examines energy use of individual energy "end-uses" (appliances, heaters, air conditioning, etc) and then anticipates the energy consumption on a larger scale based on collected data (Swan & Ugursal, 2009). With the use of these two methods, changes in energy consumption from more efficient appliances, a heat wave, or even unemployment rates, can be computed.

Top-Down Method

Lukas Swan and Ismet Ugursal published a paper in 2009 in *Renewable and Sustainable Energy Reviews*, which outlines energy consumption simulation in residential housing. They describe the top-down approach as,

> ... an energy sink [that] does not distinguish energy consumption due to individual end-uses. Top-down models determine the effect on energy consumption use to ongoing long-term changes or transitions within the residential sector, primarily

> for the purpose of determining supply requirements. Variables which are commonly used by top-down models include macroeconomic indicators (GDP, employment rates, and price indices), climatic conditions, housing construction/demolition rates, and estimates of appliance ownership and number of units in the residential sector (Swan & Ugursal, 2009).

The top-down method inputs historical data into its calculations and is valuable for long term forecasting. Energy companies are likely to use a top-down approach when setting energy prices and determining energy distribution policies. One disadvantage to the top-down method is that it does not account for individual "end-uses" and therefore cannot create different simulations to emulate the use of more efficient appliances in a home (Swan & Ugursal, 2009). Moreover, because this method is based upon historical data, it has "no apparent capability to model discontinuous advances in technology" (Swan & Ugursal, 2009).

Bottom-Up Method

The bottom-up method projects energy consumption based upon energy consumption data collected from private residences.

> [Bottom-up models] can account for the energy consumption of individual end-uses, individual houses, or groups of houses and are then extrapolated to represent the region or nation based on the representative weight of the modeled sample…Common input data to bottom-up models include dwelling properties such as geometry, envelope fabric, equipment and appliances, climate properties, as well as indoor temperatures, occupancy schedules and equipment use (Swan & Ugursal, 2009).

In bottom-up energy simulations there are two sub-methods: the engineering method and the statistical method. The engineering method takes into account the power ratings of specific in-home energy end-uses. One distinct advantage to the engineering method is that it does not rely on any historical data; therefore, it is very adaptable to new technologies. For example, the engineering method could simulate the effectiveness of older clothing dryers compared to more efficient ones (Swan & Ugursal 2009). The statistical method has the "ability to discern the effect of occupant behavior," which the engineering method does not take into consideration (Swan & Ugursal, 2009). The engineering method assumes occupant behavior to be a constant. The capability to account for occupants' behavior in a dwelling in an energy simulation is quite useful. The statistical method, like the top-down method, allows macroeconomic factors to affect the output of the simulation. After a large swing in the market, such as the recent economic downturn, these factors are undoubtedly important in accurately simulating energy consumption.

2.2 Existing Energy Conservation Guidelines

It is important to understand energy codes and rating systems in the United States and other parts of the world for this project in Puerto Rico. The AAE has requested the determination of the current energy usage and creation of a set of recommended efficiency techniques that could lead in the development of a home energy rating system. To determine energy usage and efficiency guidelines, the group explored the features of the International Energy Conservation Code, along with other rating systems, such as the Leadership in Energy and Environmental Design (LEED) and Residential Energy Services Networks (RESNET) Home Energy Rating System (HERS).

2.2.1 International Energy Conservation Code

Typical components found in an energy code can be obtained through the investigation of the International Energy Conservation Code (IECC). The IECC is used in many countries, such as the United States, Canada, Australia, and China (www.energycodes.gov, 2010). The IECC sets a standard baseline for energy efficient construction practices and existing home energy use. It is commonly used in conjunction with other building codes, such as the International Residential Code (IRC). The two codes differ in that the IECC pertains strictly to energy use in both residential and commercial buildings; whereas, the IRC covers all building codes (i.e. plumbing and structural) for solely one and two family residences (US Department of Energy, 2009). Energy requirements for residential buildings are similar in both codes. Chapter 4 of the IECC, titled, “Residential Energy Efficiency,” is useful in the context of this project.

IECC guidelines are based upon distinct climate regions. The separation of the climate zones is critical when assessing energy use because regions require certain energy use patterns depending upon their geographic location. Sections of the climate specific requirements of the IECC involve regulations pertaining to foundations (basements and slabs), above grade walls, skylights, windows, doors, roofs, and solar heat gain coefficients for warm climates (US

Department of Energy, 2009). Puerto Rico is located in Zone 1, which includes Hawaii and segments of Florida (US Department of Energy, 2009). The aforementioned solar heat gain coefficient (SHGC) is used to assess window thermal insulation in Puerto Rico as well as in Florida, Texas, and regions of southern California (www.energycodes.gov, 2010). Additional home energy efficiency factors that the IECC code addresses are infiltration and air leakage controls through the proper use of weathering and sealants (US Department of Energy, 2009).

2.2.2 LEED Rating System

One of the predominant energy efficiency measurements in the continental United States is the Leadership in Energy and Environmental Design (LEED) rating system. Similar to the International Energy Conservation Code, the LEED rating system emphasizes sustainable development and energy efficient practices in a variety of new and existing buildings. Created by the United States Green Building Council (USGBC) in 2009, the LEED rating system strives to "provide an outline for measuring building performance and meeting sustainability goals" (USGBC, 2009, p. 16). The LEED system is primarily used in assessing the energy efficiency of new construction sites; however, it is applicable to the group's work in Puerto Rico to identify energy saving techniques and improvements that could be made to existing housing units. In *Green Building and LEED Core Concepts Guide*, the United States Green Building Council emphasizes six major categories that are assessed under the LEED rating system: "sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and innovation in design" (USGBC, 2009, p. 2). The area of interest for this study is the LEED energy assessment criteria.

Sustainable residence models and energy efficiency practices are demonstrated throughout the work of the USGBC and the LEED rating system. In reference to the capabilities of energy efficient buildings, the USGBC states that the "focus on green building and energy efficiency can dramatically reduce costs for both commercial and residential owners, and the savings continue to grow throughout the lifetime of the building" (USGBC, 2009, p. 6). The benefits of green building and energy efficiency techniques are impressive. In a 2008 survey conducted by the United States General Services Administration on twelve green buildings, the savings and improvements consisted of 13% lower maintenance costs and 26% less energy use in these green buildings compared to conventional buildings (USGBC, 2009). In terms of meeting LEED standards, the United States Green Building Council identifies that energy retrofitting, particularly in low-cost residences, is more affordable than new construction (USGBC, 2009). While residences in Puerto Rico may not have the resources to achieve LEED Gold certification, it is probable that even small improvements and reductions in energy use, such as a decrease in air conditioning use and a reduction in the use of incandescent light bulbs, will contribute meaningful savings to the residents of the housing units over time.

The methods used by the United States Green Building Council in assessing residential energy use through the LEED parameters guided the team in evaluating the energy usage of Puerto Rican residences. The four techniques that the *Green Building and LEED Core Concepts Guide* identifies to reduce overall energy usage include decreasing energy demand, improving energy efficiency, seeking alternative energy forms, and continuous improvements regarding ongoing energy performance (USGBC, 2009). The recommendations by the USGBC applicable to this investigation include: insulating the building to resist cooling losses, making use of shaded areas for cooling, establishing energy performance targets for the community and individual residences, and incorporating feedback systems for energy monitoring that will motivate residents (www.usgbc.org, 2010). Strategies for maintaining energy efficiency involve conducting preventative maintenance on structural and electrical features, educational programs for the community, and the creation of incentives and motivation for residents (USGBC, 2009). These techniques are all viable alternatives investigated in this project.

Incorporating both technical guidelines and enhanced community awareness, the LEED rating system is a dynamic approach towards energy efficiency. In regards to feedback systems, this technique has proved to be very effective. In a study by Clive Seligman and John M. Darley, titled, *Feedback as a Means of Decreasing Residential Energy Consumption,* it was found that in a comparison of a group of people who were informed that they would receive feedback regarding their residential energy consumption to a group of people who did not receive feedback, the feedback group consumed 10.5% less electricity (Seligman and Darley, 1977). This is an interesting approach toward implementing energy efficiency practices; moreover, it is attractive for application in Puerto Rico because it focuses on stimulating community involvement in achieving energy efficiency goals. Rather than focusing strictly on creating a set of technical guidelines for residents to follow in Puerto Rico, it would also be effective toward investigating approaches, such as feedback loops, that will increase the Puerto Rican communities' awareness of their energy usage.

2.2.3 RESNET Home Energy Rating System (HERS)

The Residential Energy Services Network (RESNET) is a nonprofit organization that aims to ensure improvements on energy efficiency in new buildings. Members of RESNET create national standards for energy efficiency rating systems. These standards are recognized by the United States mortgage industry and federal government (natresnet.org, 2010). RESNET energy efficiency guidelines are applicable to numerous areas around the United States. More importantly, it is applicable in the state of Florida, which, as previously discussed, has a similar climate zone and energy requirements as Puerto Rico.

RESNET incorporates the usage of a unique residential energy measurement technique called the Home Energy Rating System (HERS) Index. This energy efficiency measurement consists of a numbered index scale that evaluates the energy use of a home. The typical HERS Index that is used by RESNET is shown below in *Figure 1*. A score of 100 represents the energy use of a standard new home in the United States, as identified by RESNET's existing energy simulations. A score of 0 means that the residence does not require any purchased energy for operation. This investigation focuses on providing energy efficiency recommendations such that the average Puerto Rican homes' HERS Index will fall more toward the lower region of the scale. In addition to providing the index score for energy usage, the RESNET HERS also produces recommendations for cost-effective improvements to the buildings.

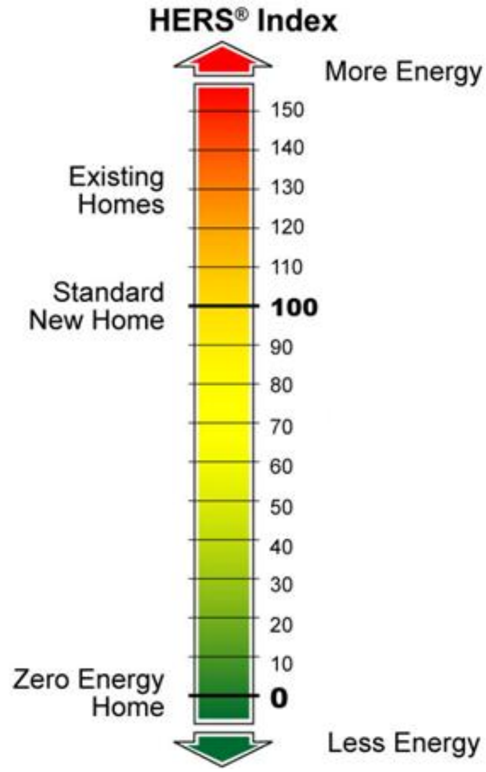

Figure 1: RESNET HERS Index (Source: natresnet.org, 2010).

The Home Energy Rating System Index is calculated using advanced energy simulation modeling. Inputs for this model are based on survey data and home audits. The modeling techniques employed by this rating system may be useful to the AAE in creating similar simulations in Puerto Rico. The HERS models the energy usage of proposed or existing buildings using accredited building simulation software, where inputs, such as number of lighting fixtures and number of ENERGY STAR appliances, are entered. The results from the simulations are then transformed into a ratio where the energy requirements of the tested building are divided by the energy usage of the standard American home and multiplied by 100 (natresnet.org, 2010). This energy percentage is used as the score shown on the HERS Index.

Development of the energy standards used in the RESNET HERS is an ongoing process. The exploration of the development of these standards is necessary for Puerto Rico to develop energy guidelines for its residents. RESNET accepts proposals for new or revised standards from any interested parties. These changes are then reviewed by RESNET's Standing Committee who publishes the comments online for public review for a minimum of thirty days. The public reactions to the proposed changes are then reviewed by the Standing Committee and sent to the RESNET Board of Directors for a vote. If passed through the Board of Directors, the proposals are sent to the RESNET Standards Revision Committee for approval or denial (natresnet.org, 2010). The success of the program is strongly attributed to community involvement and awareness. In the 2009 RESNET Annual Report, it was stated that membership of RESNET is steadily increasing where the program currently consists of approximately 1,800 members, both professionals and public citizens (Residential Energy Services Network, 2010).

2.3 Energy Use Assessments

In order to develop effective energy measurements, the project team analyzed two assessment techniques, online surveys and home audits. The research conducted on online surveys and home audits facilitated the development of the methodological tools implemented during this project.

2.3.1 Online Surveys

Electronic surveys have many of the same concerns as traditional paper or oral surveys in addition to their own unique problems. Surveys must be enticing and easily understandable for participants. The first hurdle overcome in surveys is convincing the population to participate in the survey. Electronic surveys are inherently less personal than other means of surveying: it is easy for somebody to delete an email with a survey link or skip over a survey on a webpage. This characteristic makes it important that the online survey is attractive to the population of viewers. It is popular practice to entice the potential survey participants with an incentive for participation (Andrews, Nonnecke, & Preece, 2003). Incentives attract participants and will ultimately yield more results for the survey.

Electronic surveys should also be simple to navigate and complete. The option to save work and resume the survey later has shown to improve the percentage of responses. One type of electronic survey is the email survey that emails the subject a questionnaire and requires a written response back from the participant. "Email response rates of 20% or lower are not uncommon…although rates exceeding 70% have been recorded, they are attributed to respondent cohesiveness (e.g. an existing workgroup) as often occurs in organizational studies" (Andrews, Nonnecke, & Preece, 2003). There is success in fusing both the personal aspect of an email with effectiveness of an online survey. Andrews, Nonnecke, and Preece write, "When a Web-based survey is preceded by an email inviting individuals to the URL to participate, the Web-based survey outperforms email survey participation significantly" they go on to write, "achieving response rates to an electronic survey depends very much upon how people are asked to participate". It is all too easy for a subject to ignore an electronic survey because they do not have the face to face interaction with the surveyor; this stresses the importance of making the survey attractive to the population and enticing the subjects to participate in the survey.

One advantage of the electronic survey is that the data collected can be instantaneously input into a database or spreadsheet. This makes the data easily interpretable and comparable and it is more time efficient than a traditional paper or oral survey where data must be entered and organized. The speed of data collection and interpretation may prove to be valuable in the relatively short time allocated to initiate a survey, collect and analyze data.

Presently, there are many companies or organizations that utilize electronic surveys for energy consumption information. The Energy Saving Trust of the United Kingdom, San Diego Gas and Electric Company, and RESNET all use some type of online energy survey to provide their customers with energy efficiency strategies based on their inputs to the survey. Surveys similar to these could prove to be useful for the AAE and the residents of Puerto Rico.

2.3.2 Energy Audits

As energy audits provide effective means of analyzing energy use and consumption in residences, a critical phase in this project was the development and performance of an audit to assess the current energy use in Puerto Rican homes and apartments. As previously discussed, the RESNET HERS is a pertinent energy consumption rating system for this project. The RESNET HERS incorporates the use of the Comprehensive Home Energy Audit form to obtain energy use data for audited residences. Since this research attempts to incorporate many of the same features as the RESNET HERS, the Comprehensive Home Energy Audit (shown in Appendix C) provides a model for the audit developed in conjunction with this project. In a presentation titled "Making Work Orders Work: Utilizing the Home Performance Assessment

(The Comprehensive Home Energy Audit)" given at the 2009 RESNET National Conference in New Orleans, Louisiana, Rich Moore provides a thorough description of the purpose, procedures, and assessment techniques of the Comprehensive Home Energy Audit.

In analyzing a number of audits, it is evident that a clear purpose and procedure must be defined. The purpose of the Comprehensive Home Energy Audit is "to cause improvement to be made to the audited home" (Moore, 2009). In addition, the audit includes "evaluation, performance testing and proposed treatments for improvement of an existing frame" (Moore, 2009). The major procedures included within the Comprehensive Home Energy Audit include: measurement and performance testing, combustion appliance testing, computer simulation analysis of the home's energy performance, and calculation of the energy and environmental savings from improving home energy performance (Moore, 2009). These procedures allow the auditor to evaluate the scope of work on the home to improve its energy efficiency. After the audit, it is the duty of the auditor to guide the homeowner to a certified contractor who will make the necessary renovations (Moore, 2009).

The home assessment audit evaluates various criteria that contribute to residential energy use by following specific techniques: examination of utility bills, insulation, air leakage, heating and cooling systems, ventilation, hot water use, appliances and lighting, windows, and testing for occupant issues. Investigating these components provides the auditor with a complete set of data to effectively measure the energy use of a residence. The testing methods incorporate the usage of a number of data collection tools, such as a kilowatt meters, digital pressure gages, combustion analyzer, duct blaster, and digital and infrared cameras (Moore, 2009). For this project, the limited time and resources made it impractical to use many of these tools for the energy audit. Due to these constraints, the audit used to evaluate the Puerto Rican residences was simpler than the RESNET Comprehensive Home Energy Audit.

One of the main points of Rich Moore's presentation outlines behavioral suggestions for the auditor. When auditing the Puerto Rican residences it is imperative that group members remain professional at all times and understand how to behave around the residents of the homes. The initial introduction to the owner of the audited home is a critical phase. It is important that the auditor is polite and attempts to act as non-invasive as possible. Residents need to be clearly told the purpose of the audit and that their privacy will not be disturbed. In order to take any photographs within the residence, the auditor must ask permission from the homeowner. The overall goal is to make the residents feel as comfortable as possible with the audit process.

Moore indicates that an auditor must be able to multi-task and take on numerous roles that include: serving as building scientists, detectives, social workers and therapists, and business people (Moore, 2009). In assuming these multiple roles, the auditor ensures that he or she remains professional while working as efficiently as possible. It is critical for the auditor to work safely throughout the home assessment process. If he or she is not comfortable or not knowledgeable about certain measurement procedures, it is highly suggested that this person ask for additional help.

2.4 Energy Saving Alternatives and Practices

In order to develop recommendations to increase energy efficiency and conservation, the capability of alternative energy in Puerto Rico as determined by the AAE, energy efficiency programs in similar climate zones, existing case studies, and incentive programs and governmental support in Puerto Rico were examined.

2.4.1 Capability of Alternative Energy in Puerto Rico

In 2008, the AAE published an article, titled, “Renewable Energy Targets Achievable for Puerto Rico’s Renewable Energy Portfolio Standard.” As defined in the literature, a renewable energy portfolio standard (RPS) is, “designed to increase the use of renewable energy for electricity production by requiring that a specified percentage of the electricity for the state be generated from renewable sources” (AAE, 2008). This report compares renewable energy sources such as biomass, ocean and solar thermal, wind energy, and micro-hydro based on three criteria: footprint estimate, capital cost estimate, and electric energy production estimate. Furthermore, it acknowledges the difficulty in comparing various sources because their rating systems are incompatible. The study does not cover energy conservation or efficiency (AAE, 2008).

The study's results outline the advantages and disadvantages for each energy source. The report suggests that photovoltaic (solar) energy is the most effective and least intrusive energy source for Puerto Rico. In fact, photovoltaic roofs on 65% of the residences could provide all of the electrical energy generated on the island (AAE, 2008). Despite this impressive statistic, this technology is very expensive and not always a viable option for residences.

2.4.2 Energy Efficiency Programs in Puerto Rico

Although there are no guidelines for energy conservation in housing in Puerto Rico, the AAE developed a set of guidelines for government agencies in 2009. These guidelines were developed by use of energy auditing, and although not all of the goals of this study are the same, many of the principles driving the government study are pertinent. Both the group's focus and the government documents stress energy efficient appliances and energy use awareness. The introduction of *Guidelines on Energy Conservation Measures in Government Agencies* states: "The benefit of investing in such projects is that the investment is recovered and surpassed the short to medium term" (Guidelines, 2009). These principles carry over to this study as we recommended strategies to reduce the long-term energy costs for residents of Puerto Rico.

In October of 2009, the American Reinvestment and Recovery Act (ARRA) gave the Puerto Rico Energy Affairs Administration $9,593,500 to fund alternative energy and energy conservation projects. This funding was given to Puerto Rico under the Energy Efficiency and Conservation Block Grant (EECBG). The EECBG's goals for states and territories are: to reduce the emissions of fossil fuels in an environmentally and economically friendly manner, increase energy efficiency, and reduce the required energy use in different establishments. In particular, projects funded by this grant are asked to focus primarily on energy efficiency and conservation (Financial Assistance Funding Opportunity Announcement, 2009).

Using funds from the ARRA, the AAE in conjunction with the Puerto Rican Infrastructure Financing Authority (AFI) developed a rebate program for energy efficiency updates in non-profit, government, and commercial organizations. These entities are required to apply using the designated paperwork along with projected costs for material and installation costs for these updates. To receive the rebate, the updates must be completed within six months of being accepted and a professional energy audit must be performed on the building. Although the organizations will receive a rebate covering the costs necessary to complete this project, they will become exempt from other tax credits and incentive programs that may be applicable (Building Energy Efficiency Retrofit Program, 2010).

ENERGY STAR product incentives have become a popular technique to promote energy conservation in residences. The ENERGY STAR program works in conjunction with the Environmental Protection Agency (EPA) and Department of Energy (DOE) to reduce the energy costs with more efficient appliances as well as guidelines to a more energy efficient lifestyle. These applications are rated based on standards set by both the EPA and the DOE (energystar.gov, 2010). Using funds given to the territory from the ARRA, the AAE provided rebates to residents who purchased ENERGY STAR rated products (Guidance to Dealers and Suppliers of Goods on ENERGY STAR Program Rebate, 2010).

Puerto Rico participates in the Weatherization Assistance Program (WAP), which is a voluntary program that works toward reducing energy consumption in homes by making them more energy efficient. In particular, Puerto Rico is currently taking part in an air conditioning assistance program funded by the WAP. This program states that the AAE will fund the installation of air conditioners in eligible residences; however, it will not cover the additional energy costs to the residences that an air conditioner creates (Assistance Program the Air in Puerto Rico, 2010).

In addition to these programs, on March 22, 2010 the AAE took part in the launch of the "Hagamos a Puerto Rico Verde" campaign. This campaign utilizes television commercials and billboard signs to educate the public on different conservation techniques such as unplugging unused appliances, turning off lights when they are not in use, and replacing incandescent light bulbs with compact fluorescent lamps (puertoricoverde.net, 2010).

2.4.3 Energy Efficiency Programs in the United States and Similar Locations

Energy conservation and efficiency programs in Florida were investigated for this review. It was noted that very little of the funding from the WAP went toward improvements in residences to increase energy efficiency. The only program noted in this study is the Weather Care program from the Tampa Electric Company that offers free home improvements to weatherize homes for seniors sixty years or older and o a fixed income. All other programs focus on helping low-income families pay existing energy bills (FY 2009/2010 Low-Income Energy Programs, 2010).

Guam, another U.S. territory within the same climate zone as Puerto Rico, was also examined for this literature review. Guam shares many similar qualities with Puerto Rico such as its climate, large dependency on fossil fuels (Camacho, 2009), and its recent involvement with the WAP (DOE, 2009). One promising program Guam's Energy Department developed is the Energy Lighting Audit. This program allows individual residences, as well as businesses, to apply to the energy department to receive a free audit performed by the energy department to determine the current power usage and energy consumption. Not only does the audit provide these figures, but it also provides energy conservation recommendations (Energy Lightning Audit, 2010).

2.4.4 Energy Conservation Case Studies

Bermuda is an island nation that possesses geographic and energy characteristics similar to Puerto Rico. Moreover, the residents of Bermuda are also experiencing hardships due to reliance on imported oil as the major means of electricity generation. In a 2009 report, titled *Energy Green Paper: A National Policy Consultation on Energy*, the Department of Energy of Bermuda investigated the energy sources on the island and potential alternative means for solving the energy efficiency issues. The study found that the major sources of residential energy on the island were air conditioning systems and lighting products (Bermuda Department of Energy, 2009). Judging from preliminary data from the Puerto Rican Energy Affairs Administration, it is evident that the sources of energy use by Puerto Rican residents parallel those of Bermuda.

The Bermuda study identified an array of viable options to increase energy efficiency in Bermuda. One of the major solutions to the energy issues proposed was the further investment in alternative energy sources, such as wind, solar, and hydropower. Another energy efficiency solution that the study discussed involved the potential passing of a Customs Tariff, which would "regulate the importation of key energy consuming technologies such as air conditioning systems, lighting products, other electronic appliances and vehicles" (Bermuda Department of Energy, 2009, p. 4). A third strategy identified was the electrical companies incorporating a time of usage policy whereby specific appliances, such as air conditioners, were only allowed to be run for certain time limitations (Bermuda Department of Energy, 2009). A major emphasis of this strategy involved promoting the use of air conditioners during non-peak hours to effectively distribute the energy load. The energy conservation techniques identified in the Bermuda energy report are applicable to the residences in Puerto Rico.

As demonstrated by the Bermuda energy report along with numerous other case studies, there is significant potential for energy conservation on islands such as Puerto Rico. A case study conducted by Amporn Kunchornat, Pichai Namprakai, and Peter T. du Pont, titled, *The Impacts of Climate Zones on the Energy Performance of Existing Thai Buildings*, examines the effect of various climate zones on the energy requirements of building and residences in Thailand. Thailand has a warm, tropical climate zone with similar energy sources as Puerto Rico. A major point taken from this study is that in hot and humid countries, such as Thailand and Puerto Rico, cooling demand through the use of fans and air conditioners account for 50-60% of the total energy consumption in a building (Kunchornat, Namprakai, and Pont, 2009). The need for the significant degree of air coolant systems is due to heat gain through the building envelope, referred to as the overall heat transfer value (OTTV). This measure is a function of a number of variables that include: "weather data, solar intensity, building orientation, and size and shape of the building." (Kunchornat, Namprakai, & Pont, 2009). In the similarly warm climate of Puerto Rico, it is useful to investigate the building envelopes of the residences and analyze their contribution to thermal heat storage and air conditioning requirements.

In 2005, the Puerto Rico Department of Housing researched the impact of building materials on house temperature in different cooling conditions. The two conditions examined were use of natural ventilation and mechanical cooling (air conditioning). Typical weather conditions for Puerto Rico were modeled for the different cooling methods and building materials. It is recommended that for both natural ventilation and mechanical cooling homes, the building materials be either wood and insulation or concrete and insulation to ensure energy efficiency and comfortable living conditions. Implementing techniques, such as using fluorescent lighting, propane stoves, energy efficient appliances, solar water heaters, and natural lighting can reduce energy costs by approximately 30% in both naturally ventilated and mechanically cooled housing (Monte, 2005). This study further investigates the use of these energy saving techniques.

2.5 Summary

This literature review explored numerous topics pertaining to this residential energy project for Puerto Rico. An understanding of electricity generation and usage in Puerto Rico within individual households is necessary, particularly when dealing with the broad topic of energy consumption. A review of the literature also reveals a comprehensive source of energy conservation strategies and energy simulations. An understanding of the energy assessment techniques that will be used in the project (online surveying and home auditing) was obtained. The study of existing energy codes, building codes, energy efficiency efforts in similar climate regions, and governmental energy initiative programs provides insight into the potential energy efficiency techniques that could be used in Puerto Rico. The research efforts pertaining to these topics aided in the development of the methodology and completion of the objectives.

Chapter 3: Methodology

The goal of this project was to develop residential energy use guidelines to aid in creating a home energy rating system for Puerto Rico. Specific objectives of the project included determining current energy use characteristics in Puerto Rican residences and developing residential energy conservation recommendations for the Puerto Rico Energy Affairs Administration. This process utilized online surveys, walk-through audits, and energy use data analysis, which were specifically designed to complete each of the identified objectives. The methodological process is presented in *Figure 2*. Notice the overall goal of the project is outlined in red, corresponding objectives in blue, major assessment techniques in green, and specific processes/stages in purple. The timeline followed to complete the project is shown in *Table 3*.

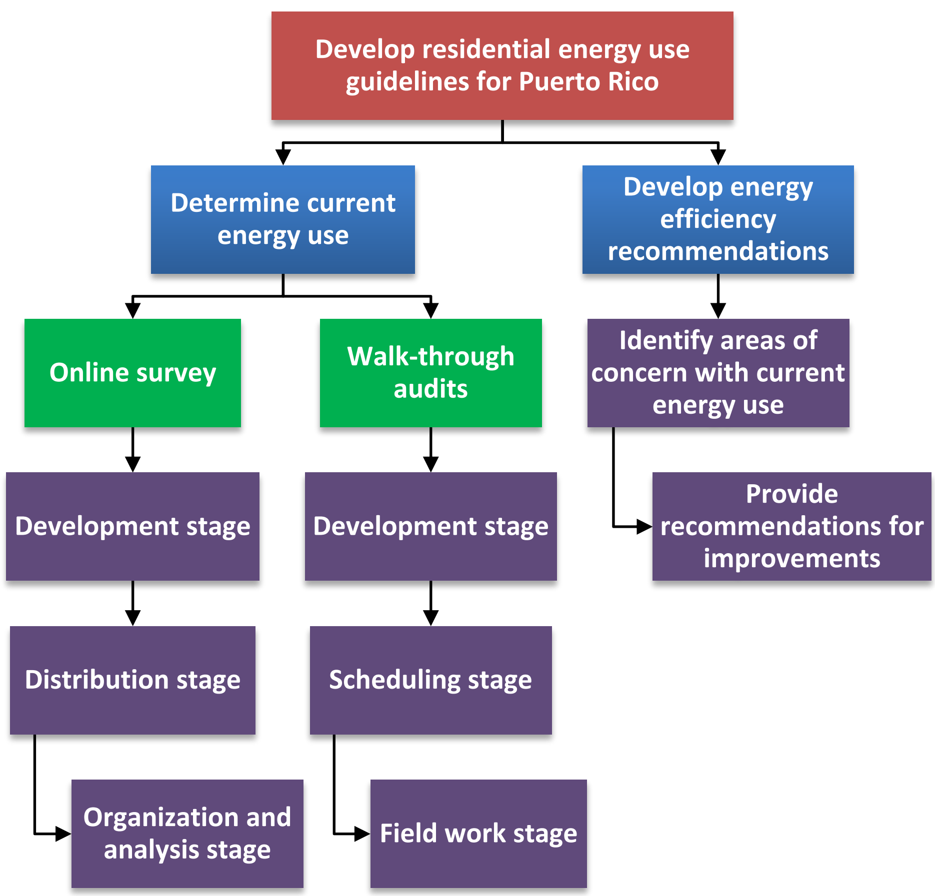

Figure 2: Methodology Flowchart

Table 3: Timeline of Project Completion

Tasks	Week 1 3/15-3/19	Week 2 3/22-3/26	Week 3 3/29-4/2	Week 4 4/5-4/9	Week 5 4/12-4/16	Week 6 4/19-4/23	Week 7 4/26-4/30	Week 8 5/3-5/7
Survey and Audit Development								
Online Surveys								
Home Auditing								
Organize/Analyze Data Collected								
Develop Current Energy Use Model								
Develop Energy Use Recommendations								
Final Report								
Presentation								

3.1 Online Residential Energy Survey

The major purpose of the online energy survey was to assess the current energy consumption characteristics of Puerto Rican residences. The development, distribution, and organization of the online survey and its results followed a multi-phase process. Once the survey was developed and accepted by the AAE, it was necessary that it was distributed to a responsive population. The survey responses were analyzed to obtain the results from the study and to provide recommendations to the AAE.

3.1.1 Development of Survey

The initial phase in the survey process involved the development of an online survey to be emailed to the public. The group chose to email the survey because it would eliminate having to go door to door. It also eliminated having to manually process all of the data. The online survey was generated using Google Documents, an effective online surveying tool where results are tabulated by the software. The group received feedback and suggestions from the AAE sponsor regarding the first draft of the survey that was developed from background research. Appropriate revisions were made based on the sponsor's suggestions. The revised survey was sent to an employee from the AAE to be translated into Spanish. A Spanish version of the survey was necessary to accommodate for the most likely language barrier.

To ensure that the online survey did not have any technical problems, the English and Spanish versions were emailed to a mailing list of approximately twenty employees within the AAE office. This procedure was used as a beta test trial for the survey. The main purpose of the survey beta test was to practice and understand how to use the data collection application provided by Google Documents. In total, the group received seven responses to the survey beta test which proved to be helpful because it allowed the group to find any glitches with the software and survey form. The team found that there was an issue with the collected data when the individual being surveyed selected responses with a hyphen. For example, if an individual chose “3-4” for the number of air conditioners in their home, it would record the result in our Google Documents folder as March 4th, 2010. The group realized that this was a simple formatting issue with the Microsoft Excel spreadsheet interface that Google Documents uses to tabulate data and this problem was easily addressed. To fix the issue, answer bins were changed from ranges with hyphens to single numerical values. In addition to these technical issues, a final section on the form was added which included a note at the end requesting that any resident interested in a free walk-through contact us at our group email address. From the beta test run, a final draft of the survey was created and approved by the AAE sponsor. The entire process for creating the final survey took about one week. Refer to Appendix B to view the survey form.

3.1.2 Distribution of Survey

Effective distribution and response rates to the online survey were essential for this project. The sponsor requested that the group obtain approximately 1,000 responses from the survey. In order to satisfy this request, it was necessary to distribute the survey to a large population to overcome low response rates that are common in electronic email surveys. Over the course of two to three weeks, the Spanish and English versions of the survey were distributed to various mailing lists provided by the AAE. On March 24th, 2010, the first wave of surveys was sent to a mailing list consisting of approximately 6,000 people from The College of Engineers and Surveyors of Puerto Rico. As the responses from this mailing list were collected, the group and AAE brainstormed to find other contacts to which the survey could be distributed. The AAE sponsor provided the group with a second mailing list consisting of approximately 8,000 people from the energy industry within the Manufacturer’s Association of Puerto Rico.

It was noted that the use of these mailing lists potentially created bias in our results. This is due to the fact that many of these people whom the survey was sent to are from the middle to upper class income levels and likely have different energy consumption and energy conservation awareness than the lower income class. The deadline for data collection from the two mailing lists was set three weeks after the first wave of surveys was sent. Though the survey remained open to the public after this deadline, the results included within this study are based upon those obtained within this time interval. The survey data was closed off on April 12th, 2010.

3.1.3 Organization of Survey Responses

As previously mentioned, the Google Documents application was utilized to collect the responses from the online survey. During the surveying period, the group and AAE sponsor decided that the most effective way to organize the data from the surveys would be to separate the data based on household occupancy. The responses were organized based on occupancy because it was understood that energy use varies between residences with different numbers of people living within them. The data organization was accomplished by importing the results from Google Documents into a Microsoft Excel spreadsheet. Within the spreadsheet, the data was sorted based upon household occupancy in three major categories: low occupancy (1 or 2 residents), average occupancy (3 or 4 residents), and high occupancy (above 5 residents). For each of these categories, the characteristics of current energy use were established based upon the answers to the survey questions. These results are presented in Chapter 4.

3.2 Walk-through Energy Audits

Walk-through home energy audits were a complimentary component to the online survey that helped assess current energy use in residences. The major purposes of the home audits were to confirm the accuracy of the results obtained through the online survey and to provide insight into additional energy-related aspects of the residence that were not covered on the survey. Due to time, resource, and experience limitations, the audits incorporated in this study were walk-through observational assessments, rather than professional audits. The legal process involved with allowing the team to visit public residences on behalf of the AAE limited the scope of the auditing procedure.

3.2.1 Development of the Walk-Through Energy Audit Form

Walk-through energy audits are an economical, time-efficient, and effective means of analyzing household energy use. This process is observational and entails field visits to the residences where important energy characteristics are noted. The audit form was originally based on the research conducted in the preliminary stages of this project and was modeled after the RESNET Comprehensive Home Assessment. This form took into account building, appliance, and human behavior characteristics such as the types of building materials used, the use and condition of insulation, the number of significant appliances (air conditioners, computers, etc.), appliance maintenance, shades or partitions, thermostat settings, and the number of existing energy efficiency devices (i.e. fluorescent light bulbs and ENERGY STAR appliances). Refer to Appendix C to view the RESNET Comprehensive Home Assessment audit form and Appendix D to view the original audit form developed by the group.

In order to gain an understanding of how the walk-through audits would work, beta tests were performed at two residences assigned to the project team by the AAE. All four team members were present for the walk-through audit beta test. These practice walk-through audits made it apparent that the audit needed to be revised to eliminate construction characteristics and to include a larger interview section. The beta audits also indicated proper behavior and communication with the residents while visiting their households and gave the project team an understanding of the time needed to thoroughly complete this audit.

The final revisions made to the audit were driven by the team's experience in the walk-through audit beta test. Due to time and equipment constraints, as well as a lack of professional training, nearly all of the building characteristics within the original audit were eliminated. Residence size and air conditioned area were the only remaining building characteristics to be examined. Although many building characteristics were removed, the emphasis and criteria in analyzing both resident behavior and appliances were modified to be more in-depth. These audits were used mainly to reinforce the data collected by the group through the residential energy use surveys and to gauge specific behavioral characteristics that could not be obtained through an online survey.

3.2.2 Scheduling of Audits

At the end of the online energy survey, there was a note asking the individual to send an email to the group's Gmail account with contact information if they were interested in a complimentary audit. Upon receiving the survey results, the group received many in-home observational audit requests. Due to time restrictions and the high volume of audit requests, the group decided that it would be beneficial to organize the audit requests into folders based on location. For example, when an individual would request an audit from San Juan, their email request was placed in the "San Juan folder" on the team's Gmail account.

Utilizing the organization of the requests in separate folders, the group was able to develop an auditing schedule and address book with Microsoft Excel. The schedule allowed for four two-hour blocks per day for two weeks for the audits to be performed. This period would give the group enough time to arrive on site, perform the audit, and travel to the next site without being late. The group used the organized email folders to create an address book in the Microsoft Excel spreadsheet that had each individuals name, address, email address, and phone contact. The group planned to schedule the audits based on times that were accommodating to the home owners as well as residence location.

After many discussions with AAE personnel, the group learned that it was not possible to perform walk-through audits in the field in the manner originally planned. The group was unable to perform walk-through audits on the homes of the general public due to legal concerns expressed by the AAE. To respond to this issue, the group performed walk-through audits on specified residences of workers within the AAE. Emails were sent to eight members of the agency who were willing to receive the audit. The audit times were scheduled based on availability of each individual.

3.2.3 Process for Walk-Through Audits

The entire auditing process took about two weeks to complete audits for the five residences that were visited in this study. Audits were performed in either groups of two to four team members. Two members were considered to be the ideal amount of people for the audit as to not overwhelm the residents during the procedure. The walk-through audit results were recorded as they were performed and the different sections were split up between the team members. Transportation to the residences was provided by AAE personnel. The procedures used for the walk-through audit consisted of a brief resident interview along with an observational assessment of interior appliances and energy consumption features. Refer to Appendix E to view the final audit form used in this study.

3.3 Energy Conservation Recommendations and Deliverables

Results from the online survey were instrumental in developing a set of energy conservation recommendations for the current energy consumption model in Puerto Rico. With 883 responses, the survey results showed major trends in energy use among the different occupancy categories. Major sources of energy consumption were noted by the group and identified as potential areas for improvement. Based upon these identified trends, the group was able to develop strategies that may alleviate the issues associated with energy inefficiencies. The residential energy efficiency recommendations provide Puerto Ricans and the AAE with areas to focus their attention in regards to home energy consumption. The recommendations are supported by actual data since they were developed from the results obtained from the surveys and audits. The simplicity of the recommendations is promising in that fact that they are feasible for residents to implement in their homes, thereby increasing the odds of a more energy efficient island.

The final deliverables of the project were presented in a final report and presentation to the AAE. The material within the report included the characteristics of current energy consumption shown with the survey and walk-through audit results, and recommendations for improvements in residential energy efficiency. These final products are the direct result of the methods outlined within this chapter.

Chapter 4: Results and Analysis

The primary objectives of the project were met through the organization and analysis of the survey and audit results. Current energy use characteristics are presented in this chapter based on the survey results and reinforced by audit results. By analyzing the energy consumption data, the group identified major problem areas and developed energy conservation recommendations that are presented in Chapter 5.

The residential energy online survey was distributed by AAE personnel and data was collected and analyzed by the project group. The group received 883 total survey results out of approximately 14,000 that were sent out to the two mailing lists. It should be noted that the survey results may have a bias due to the demographic characteristics of the mailing lists to which the surveys were distributed. The survey was sent out to two different professional societies and does not best exemplify Puerto Rican residences as a whole. The salaries of the separate social classes in Puerto Rico can be seen in Appendix A. Despite this potential bias, the results were used to create a current energy model for a typical Puerto Rican home which is based on the responses of the survey population.

With the results compiled into Microsoft Excel through the Google Documents application, the group sorted and categorized the collected data. There was no "double checking" method of the data as it was directly copied from the Google Documents application. The data was organized into three main categories based on residential occupancy: low occupancy consisting of 1 to 2 residents, average occupancy consisting of 3 to 4 residents, and high occupancy consisting of 5 or more residents. This stratification was requested by our sponsor and provided an efficient method to organize the collected data. *Figure 3* shows the breakdown of the different occupancy groupings from the survey population.

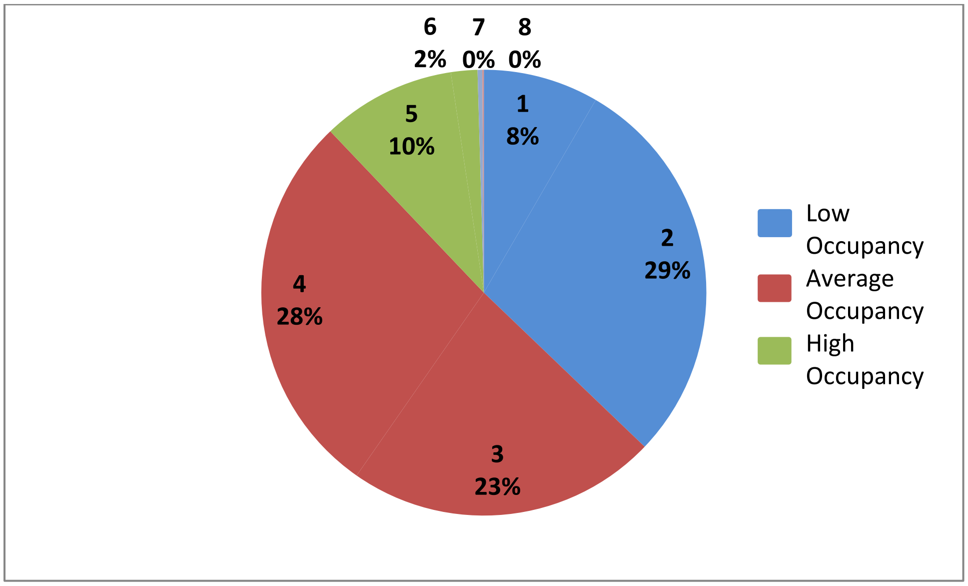

Figure 3: Occupancy (number of people) of Residences from Survey Population

The occupancy profile suggested that there were an adequate percentage of residences from each occupancy group from which to draw data. The established occupancy groupings were sufficient for this study. Although the number of people within each occupancy group varied, the results within this section are presented in percentages of residences within each occupancy cluster. This technique allowed for the comparison between the three distinct occupancy groups.

4.1 Survey Results for the Current Residential Energy Model

Using the survey results from the surveyed population, the group devised a typical model that exemplified energy characteristics of the Puerto Rican residences. The results of the survey were analyzed using two separate methods. One method, as mentioned above, categorized the survey results into three groups based on residential occupancy. This process compared and noted any trends within the three occupancy levels. The survey data was also presented and analyzed in its entirety and referred to as the typical model where the data is not divided into group categories. This analysis was used in the creation of the current energy model for a typical residence in Puerto Rico.

4.1.1 Household Information

Notable results from this section of the survey include those pertaining to residence size as well as the date of construction of the residence. These factors influence energy consumption.

Residence Size

Question 2 of the survey asked individuals to report the approximate size of their residence. Comparative results between the residence size and occupancy groups are shown in *Figure 4*.

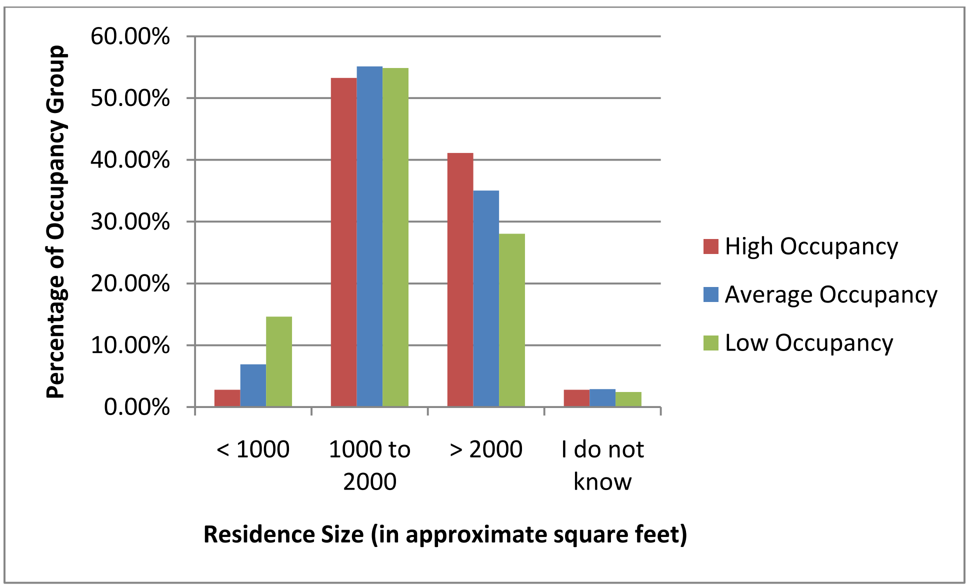

Figure 4: Comparison of Residence Size between Occupancy Groups

Regardless of the occupancy level, over 50% of each grouping has an average residence size of 1,000 to 2,000 square feet. Each of the three bins show intuitive results in that occupancy is linked with residence size. The three residence size bins were selected by the project liaison, who received the information from the Home Owners Association. These three groupings are considered to be the standard in Puerto Rico and the approximation of the bin results to a normal data distribution shows that these bins were appropriate for the collected data.

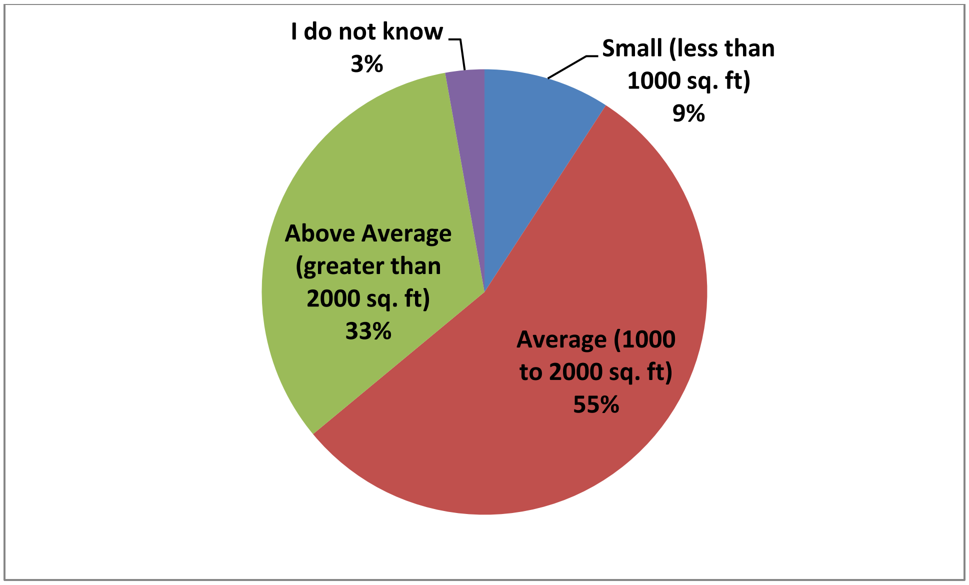

Figure 5: Typical Model for Residence Size

The data in *Figure 5* shows that 88% of the survey population lives in a residence larger than 1,000 square feet. It is assumed that a larger home will consume more energy than a smaller home. The data indicates that a majority of the sample population has an average size residence. The average residence size bin of 1,000 to 2,000 square feet contains 55% of the surveyed population, which may be high for one category. Results may have been more specific if the design of this survey question were improved. Potential improvements to this question include dividing the average bin size into two smaller groups and putting an upper bound on the above average home size. These techniques would possibly yield more detailed results.

Date of Construction of Residence

Question 3 of the survey regarded the construction year of typical homes of the surveyed population in Puerto Rico. Results are presented in *Figure 6*.

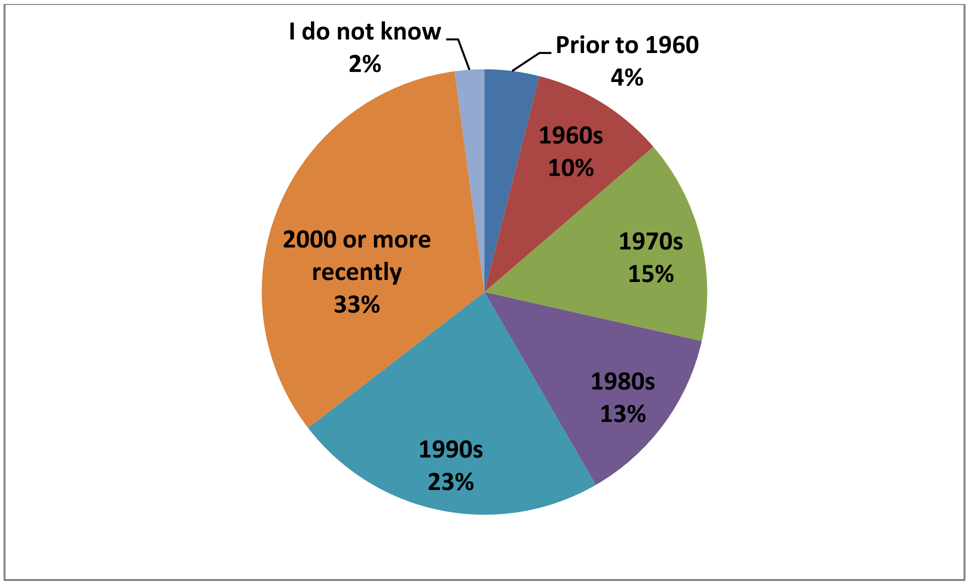

Figure 6: Typical Model for the Date of Residence Construction

The data indicates that 56% of the surveyed population lives in homes constructed from 1990 to the present. It is probable that these homes use more energy efficient products than those of earlier years. Newer homes are likely to be more energy efficient because the ENERGY STAR conservation program was created in 1992 by the United States Environmental Protection Agency and Department of Energy (energystar.gov, 2010). It is possible that older homes have been renovated with ENERGY STAR appliances; however, this was not specified in the survey.

4.1.2 Current Energy Use

Some of the current energy use characteristics of Puerto Rican homes were determined through nine questions on the survey. Results from the energy use section of the survey are presented within this section. Additional supporting data and graphs are presented in Appendix F.

Number of Operating Air Conditioners

Question 6 of the survey asked for the number of operating air conditioners per residence. *Figure 7* compares the answers of the number of operating air conditioners between the different occupancy groups. *Figure 8* shows the typical model of the sample population for the number of air conditioners per residence.

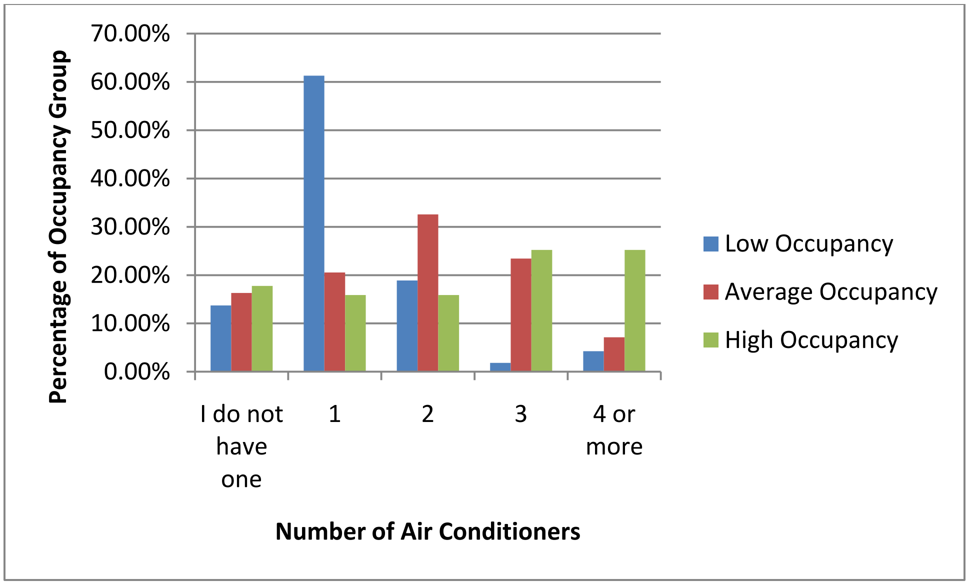

Figure 7: Comparison of the Number of Operating Air Conditioners

Figure 7 confirms intuition in that the greater the occupancy, the more air conditioners a residence uses. Among the low occupancy group, the median is one operating air conditioner per residence. Within the average occupancy group, the median is two air conditioners per residence. Within the high occupancy group, the typical response was three to four air conditioners. Data indicates that the number of people who do not have air conditioners is independent of occupancy level.

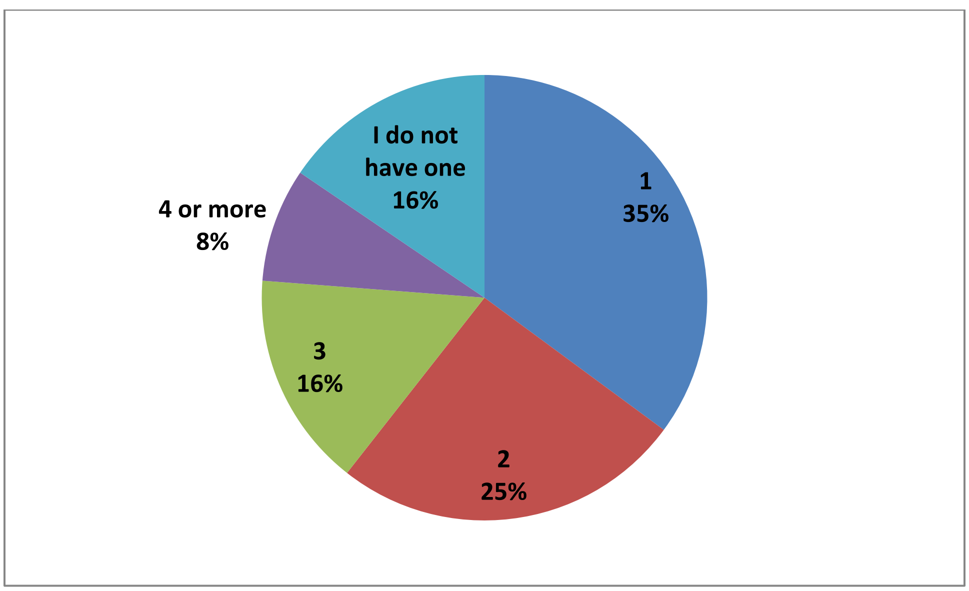

Figure 8: Typical Model for the Number of Operating Air Conditioners

The data in *Figure 8* shows that one air conditioner per residence is the most popular response among the entire surveyed population. It is surprising that 16% of the surveyed population in Puerto Rico do not have an operating air conditioner in their homes. Among this percentage, it would be interesting to investigate the alternative means of cooling. An additional survey question could have asked members of this percentage of people who did not have air conditioners to specify the other forms of cooling that are used within their residences. These cooling techniques may consist of other appliances, such as fans, as was seen with some of the audited homes in this study; however, they may also consist of natural techniques, such as natural shading and ventilation.

Types of Air Conditioners

Question 7 of the survey asked for those people who used air conditioners within their homes to specify the type. Results regarding the types of air conditioners are presented in *Figure 9*.

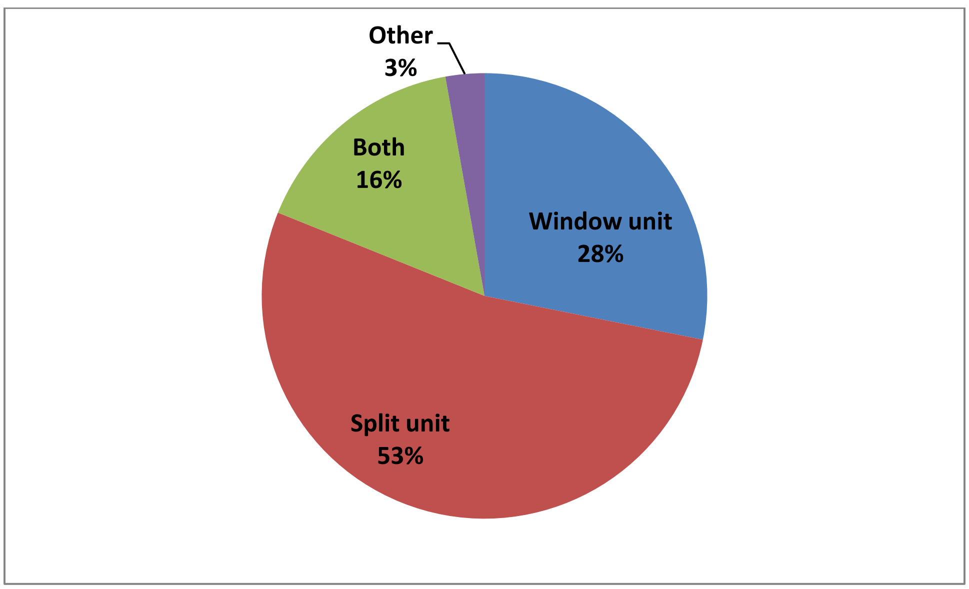

Figure 9: Typical Model for Types of Air Conditioners

The data indicates that the majority of residences consist of split unit air conditioners. Window units were the second most common type of air conditioners. In talking with professionals within the AAE, the group was told that split unit air conditioners are generally more efficient than window unit air conditioners. The fact that nearly 70% of the surveyed population uses split units indicates that there may be little room for improvement in the types of air conditioners being used in the residences surveyed. Since split units are effective in these residences, there is an increased likelihood that split units are easily attainable in Puerto Rico and may provide a means of saving energy. The "other" response, which made up 3% of the results, shows that only a small fraction of the population who owns an air conditioner use other forms such as central air conditioning.

Daily Air Conditioner Use

Question 8 of the survey evaluated the hourly usage of air conditioning per day. The typical model for daily air conditioner use of the surveyed population is presented in *Figure 10*.

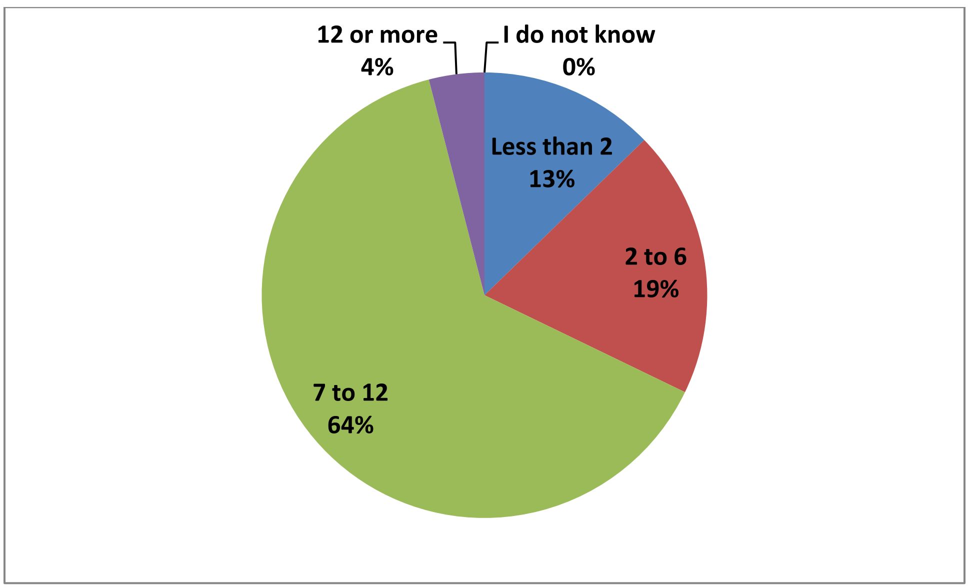

Figure 10: Typical Model of Daily Air Conditioner Use (in Hours)

The results show that the majority of the survey population runs their air conditioning between 7 to 12 hours each day. In examining the comparison between daily air conditioner use and occupancy (shown in Appendix F), it was observed that the time of air conditioner use is independent of occupancy categories. The time of air conditioner use is based on residents' living habits. The survey did not ask residents to specify the time at which people are at home and the times the air conditioning is turned on in their homes. This additional information may have been beneficial to this study in regards to understanding resident behavior. Also, dividing the 7 to 12 hour response bin into smaller windows would have yielded more revealing results.

Types of Dryers

Figure 11 indicates the types of clothing dryers residents reported in their household, if any.

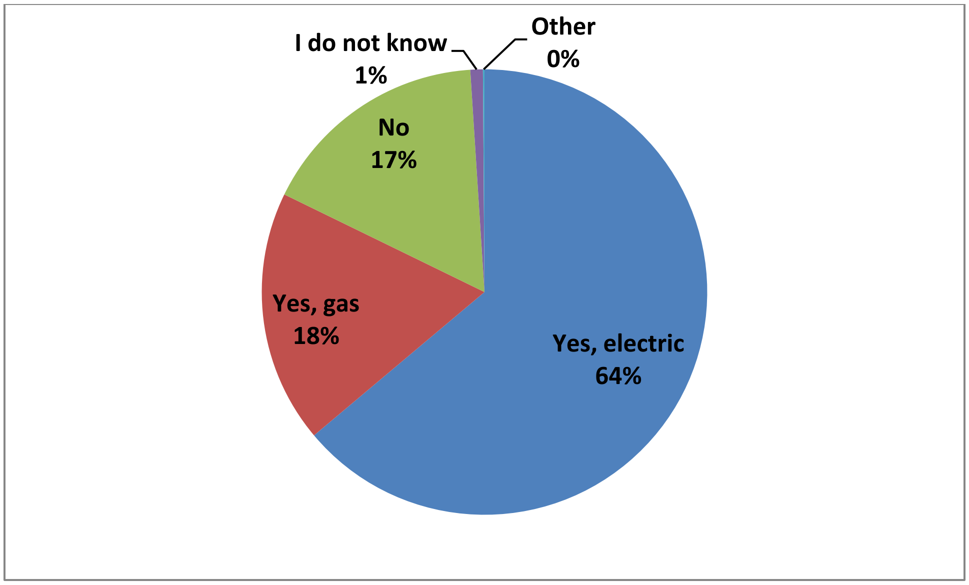

Figure 11: Typical Model for the Types of Dryers

Electric dryers are the most popular among the Puerto Rican residences by a significant margin. The remaining portion is equally divided between residents with gas-operated dryers and those who do not own dryers. Of the two types of clothes drying machines, it is unclear as to which is the most efficient, because this depends in part on the individual drying machines. Among the 17% who reported not having a drying machine, air drying or using communal clothing dryers are both viable options.

Loads of Laundry per Week

In order to measure the extent of washing machine use within the residences, the group asked on average how many loads of laundry residents do per week. A comparison between the number of loads of laundry and the occupancy groups is presented in *Figure 12*. The typical model for the average weekly number of loads of laundry per household is presented in *Figure 13*.

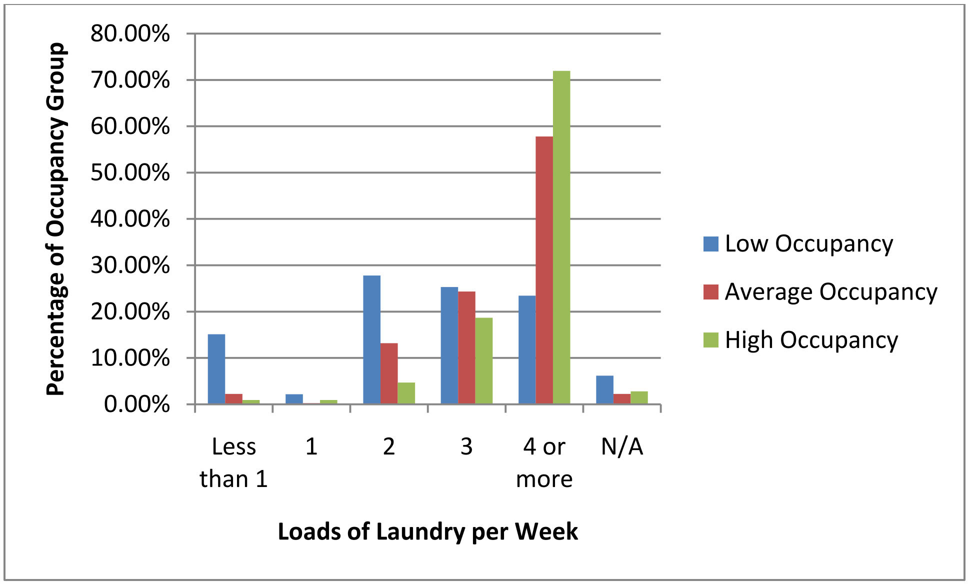

Figure 12: Comparison of Loads of Laundry per Week

The results in *Figure 12* support intuition. It is logical that the average number of loads of laundry will increase with increased occupancy levels; therefore, the high and average occupancy groups are likely to consume more energy from laundry machines use than the low occupancy group.

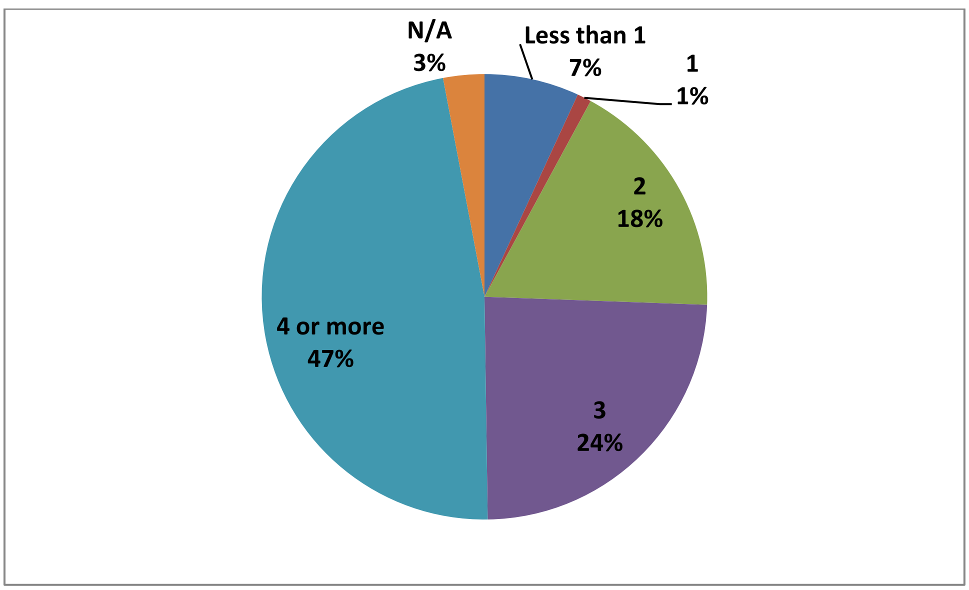

Figure 13: Typical Model for Loads of Laundry per Week

The typical model for weekly laundry machine use shows that 47% of the residents do four or more loads of laundry within their homes. This high percentage indicates a major area for improvements in energy efficiency. The high percentage of responses in this bin also indicates that the design of this survey question may be improved. Improvements may consist of creating additional response bins for responses that are greater than the four or more bin in order to determine an average number of loads of laundry. Only 3% of the surveyed population answered that they did not wash laundry within their homes (designated as N/A on the chart).

Type of Water Heater

Figure 14 displays the results for the survey question regarding the type of water heaters that are in operation in the homes of the surveyed residents.

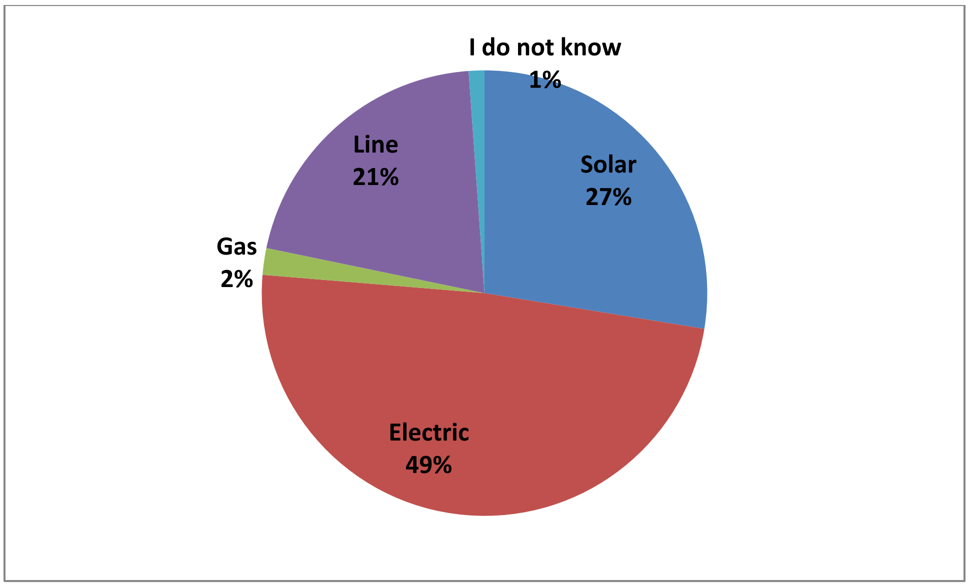

Figure 14: Typical Model for Type of Water Heater

As expected, a large percentage of water heaters are powered by electricity. This includes both the electric and line percentages as viewed in *Figure 14* above. Note that line water heaters refer to those water heaters with no storage tank. Surprisingly, solar water heaters are responsible for over 25% of the total responses which demonstrates this survey population's knowledge of solar water heating as an effective means of conserving energy.

Number of Significant Energy Consuming Appliances per Residence

In addition to dryers, washing machines, and water heaters, other major energy consuming appliances of interest to this study included televisions, computers, and refrigerators. Question 14 of the survey asked residents to specify the number of each device that they had within their households. Results for each appliance are presented within this section.

Number of Televisions

Results for the number of televisions within each residence are shown in *Figure 15*.

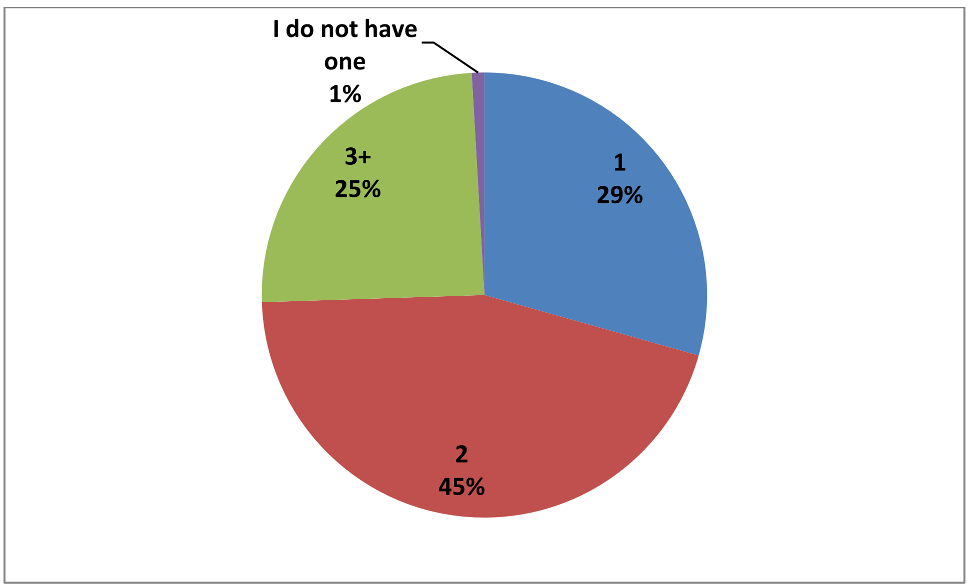

Figure 15: Typical Model for Number of Televisions per Residence

Overall, the results from this question are assuring as a majority of the responses stated that the residence had one to two televisions. In addition to the number of televisions per residence, it is of interest to further investigate the average amount of time that televisions are used within a household. It may also have been valuable for the survey to ask whether multiple televisions are turned on at the same time and whether these televisions are ENERGY STAR certified.

Number of Computers

Results for the number of operating computers within each residence are shown in *Figure 16*. Note that the number of computers includes both desktops and laptops.

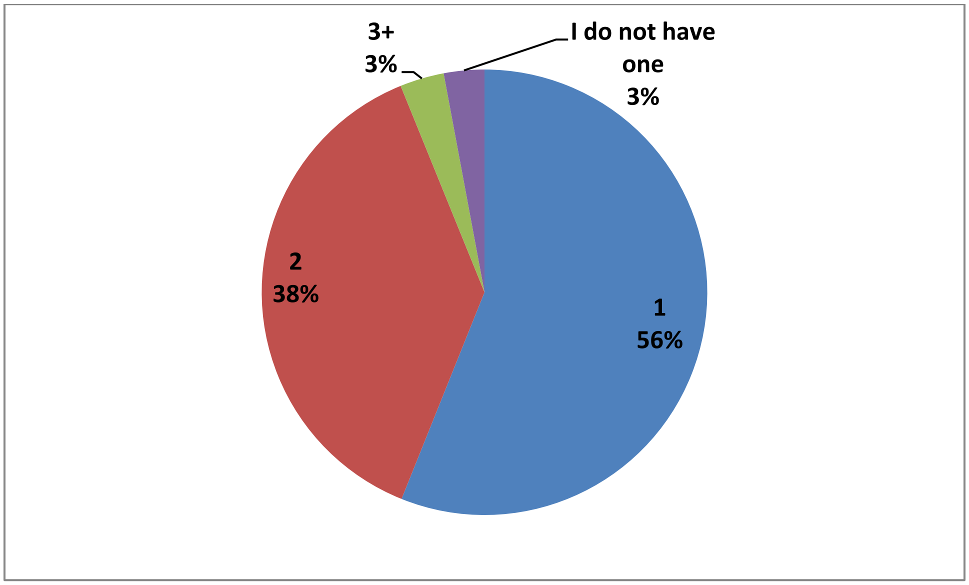

Figure 16: Typical Model for Number of Computers per Residence

The results indicate that over half of the residents operate at least one computer within their household. It is important to note that 97% of the survey population uses a computer within their homes. This supports the previous statement that the surveyed population may not represent the entire population of Puerto Rico. It is probable that there exist a higher percentage of people in Puerto Rico that do not have a computer within their home than was shown in these results; however, this data may also indicate the growth of professionalism and technology on the island.

Number of Refrigerators

Results for the number of operating refrigerators within each residence are shown in *Figure 17*.

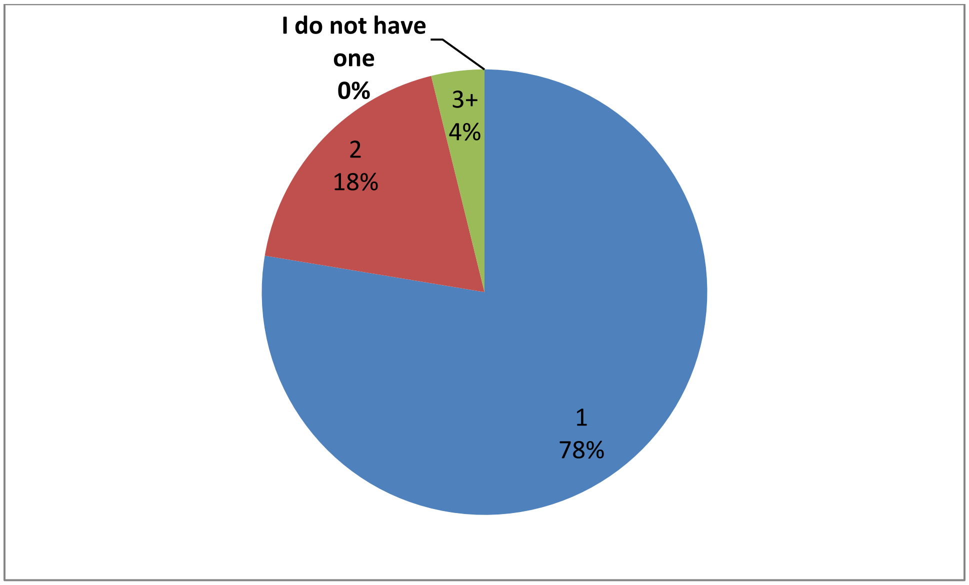

Figure 17: Typical Model for Number of Refrigerators per Residence

Most residences have only one refrigerator. The interesting aspect of this data is that 22% of the survey population has two or more refrigerators, which seems like a potential area of overconsumption. The reason for the excess number of refrigerators may be in the form of miniature refrigerators or bar refrigerators. These devices are accounted for as a refrigerator for the purpose of this study.

4.1.3 Energy Efficiency Techniques

One of the goals of the survey was to assess resident awareness of energy conservation and efficiency techniques. The survey investigated awareness of the Department of Energy's conservation program, ENERGY STAR, along with possible energy conservation techniques.

Awareness of ENERGY STAR

The results of the ENERGY STAR resident awareness survey question are shown in *Figure 18*.

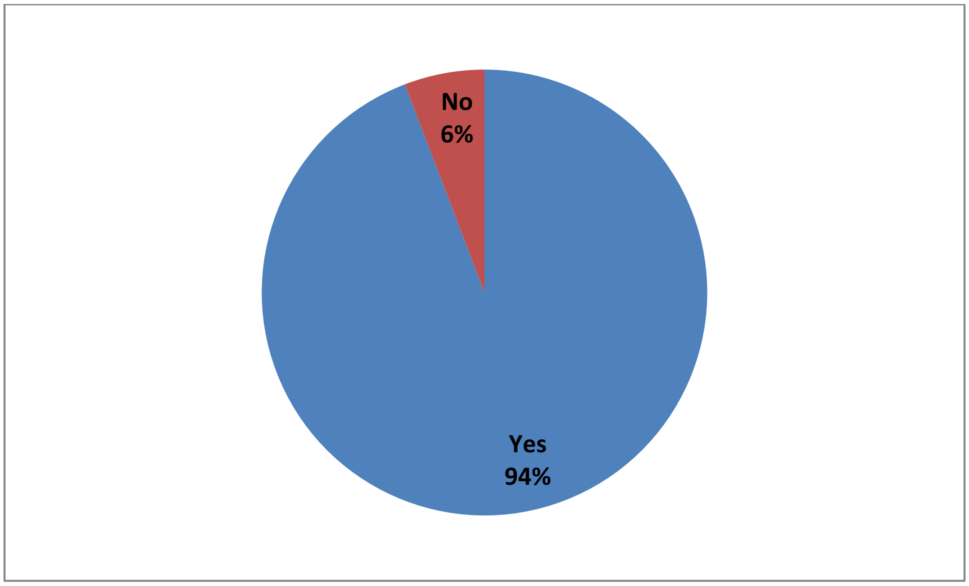

Figure 18: Typical Model for ENERGY STAR Awareness

The results illustrate that a significant portion of the survey population is aware of the ENERGY STAR program. The data exceeded the expectations of ENERGY STAR awareness in Puerto Rico. The data for this question may be skewed due to the potential bias of the population that was surveyed. This result may demonstrate inflated awareness of ENERGY STAR in comparison to the total awareness of the population on Puerto Rico as a whole.

Number of ENERGY STAR Appliances

Results for the number of ENERGY STAR appliances per residence are shown in *Figure 19*.

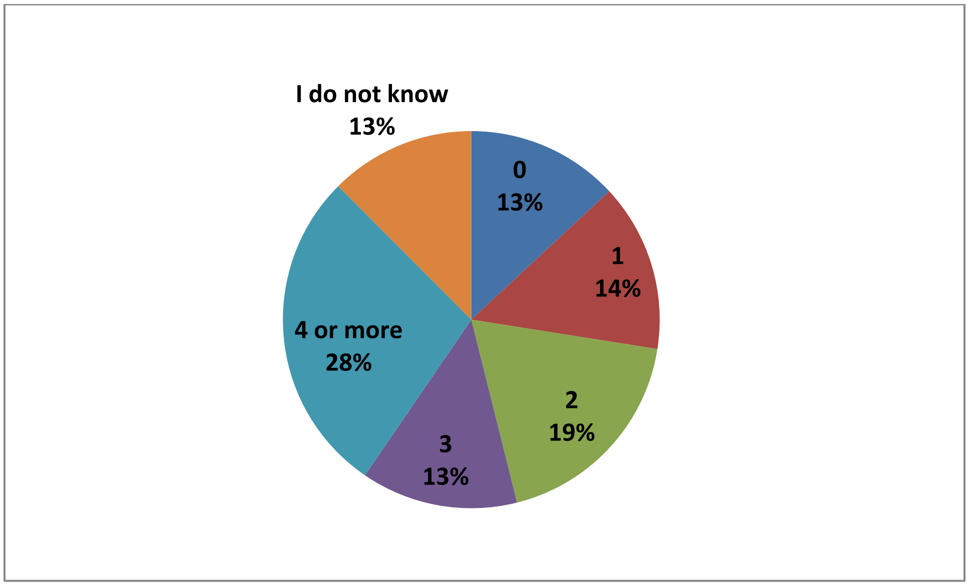

Figure 19: Typical Model for Number of ENERGY STAR Appliances

The responses from this question indicate that most of the sample population is aware of the usefulness of ENERGY STAR in energy conservation. This data shows that a significant portion of residents use ENERGY STAR appliances within their homes.

Energy Conservation Techniques

Question 18 of the survey evaluated energy conservation techniques used within residences. Due to issues with translating the data into Microsoft Excel, *Figure 20* shows the output from Google Documents which does not consist of percentages.

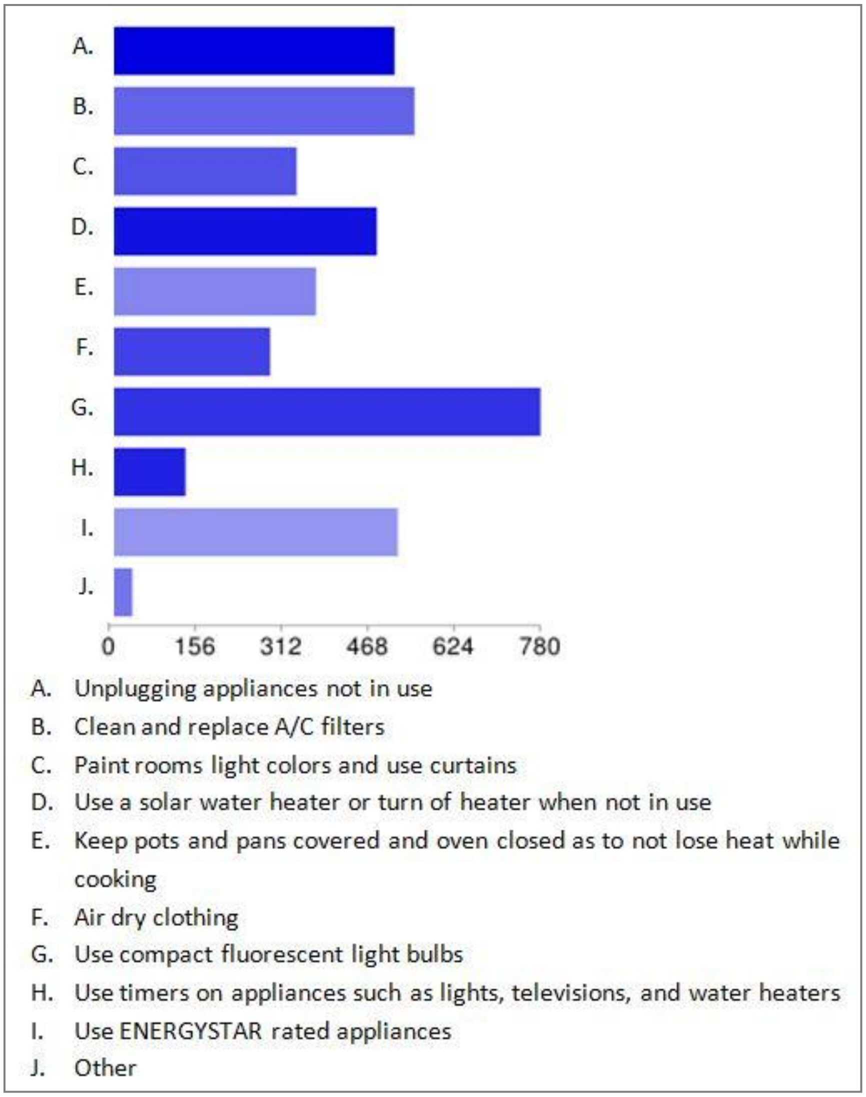

Figure 20: Energy Conservation Techniques

The most common energy saving technique is the use of compact fluorescent light (CFL) bulbs. This was not surprising because CFLs are one of the most well-known ways to reduce household energy consumption. The next most commonly implemented energy conservation strategies are unplugging appliances that are not being used, cleaning air conditioner filters, and the use of ENERGYSTAR appliances. One effective method of energy conservation that returned lower than expected results was the use of timers for appliances. The awareness and implementation of this conservation strategy can surely be improved.

4.1.4 Current Energy Consumption and Bills

Within this section of the survey, residents were asked to report their average energy consumption in kilowatt-hours as well as the average cost of their energy bill.

Comparison of Monthly Energy Consumption and Bills

The comparison of energy consumption between the occupancy groups is presented in *Figure 21*. The comparison of monthly energy bills for the occupancy groups is displayed in *Figure 22*.

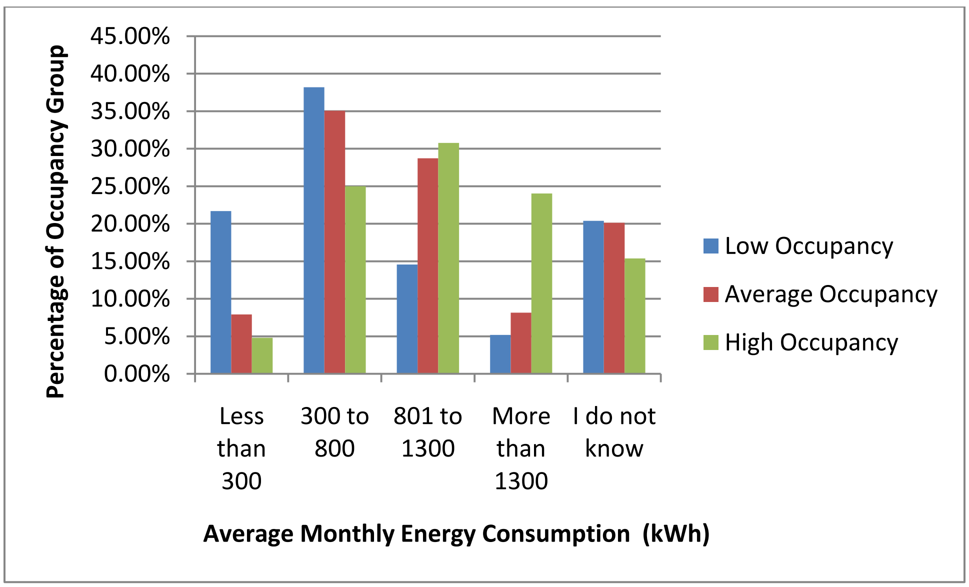

Figure 21: Comparison of Monthly Energy Consumption (kWh)

This graph shows a general trend that energy consumption in residences increases with occupancy. There are a significant number of people in each of the occupancy groups that do not know their energy consumption. This may be due to the fact that the person taking the survey was not the one who pays the household energy bill.

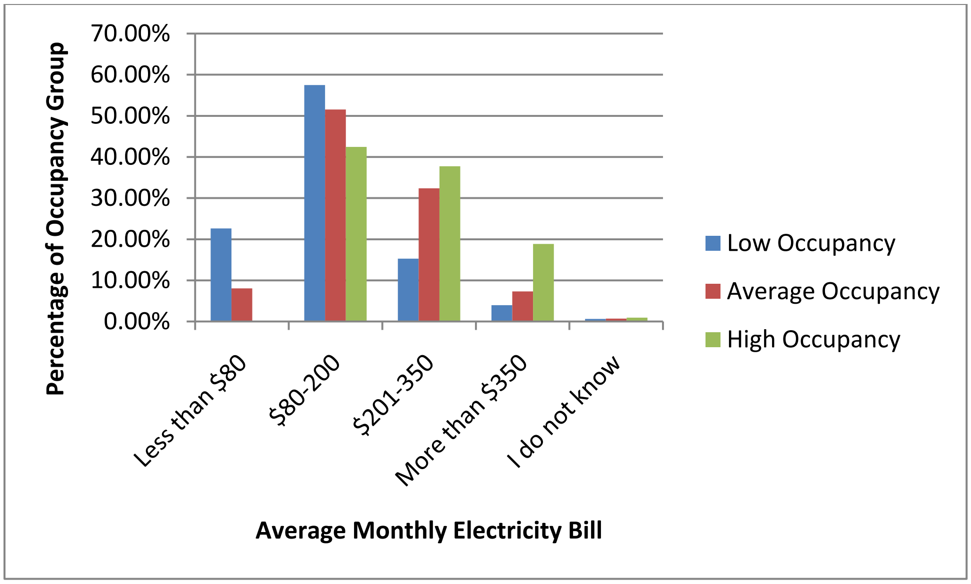

Figure 22: Comparison of Average Monthly Electricity Bill

While examining the average monthly electricity bill in regards to different occupancies, it is noted that the results are not entirely consistent with consumption. Despite this, low occupancy generally maintains the lowest electric bill costs, whereas high occupancy maintains the greatest.

Typical Monthly Energy Consumption and Costs

Monthly consumption and costs for the survey population are shown in *Figure 23* and *Figure 24*.

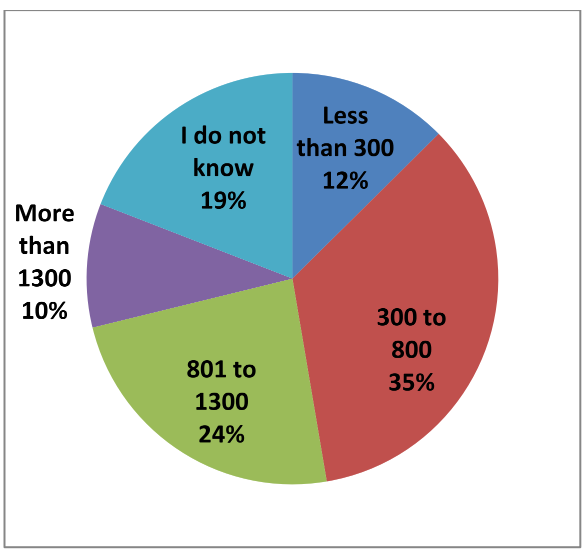

Figure 23: Typical Model for Monthly Energy Consumption (kWh)

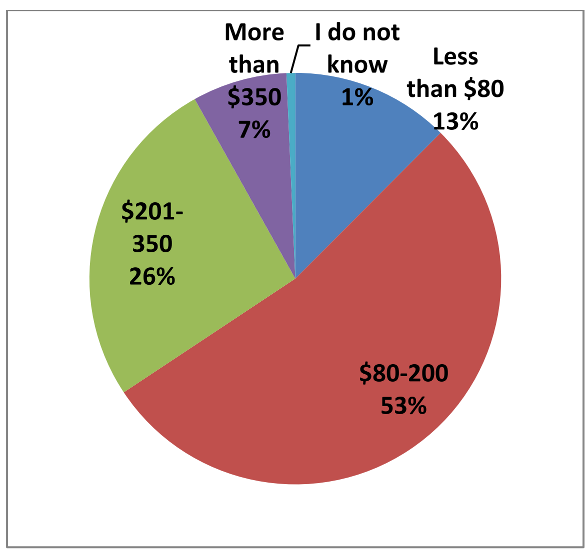

Figure 24: Typical Model for Monthly Energy Bill

The most notable comparison between the consumption and cost distributions is the difference between resident knowledge of these topics. While 19% of the residents surveyed did not know their average consumption, only 1% did not know their average cost. When the survey was developed, the price ranges were chosen to correspond with the consumption ranges. Despite this measure, the price and consumption ranges do not seem to correlate in terms of resident responses. This could be due to both fluctuations in the price per kilowatt-hour in energy as well as differences in resident estimation of both their consumption and bill costs.

4.2 Audit Results for the Current Residential Energy Model

Following the analysis of the survey results, the group used the walk-through audit results to support the collected survey data and provide insight into resident behavioral characteristics. The group initially planned to perform a large number of observational energy audits; however, due to legal complications, the group was unable to perform all of the planned fieldwork. There were some liability issues that prohibited the project team from going into public citizens' homes. Due to these complications, the group searched for alternative means to collect the data and performed five walk-through audits in the residences of AAE employees and family members.

The data collected from these audits was valuable to the study; however, it was not sufficient or reliable enough to create hypotheses regarding a typical Puerto Rican home. Thus, this section consists of a limited number of numerical results. The audits reinforced some of the analyzed survey results and also included interesting information regarding the annual distribution of the residents' energy consumption and bills, as well as insight into different demographics and typical daily routines. In order to have enough data to draw well-supported conclusions, the project team would need to perform 40 to 50 audits. The project team believes that designing and performing these few audits have laid the foundation and framework for future project teams to study energy usage through observational audits. Refer to Appendix G for the five audit forms that were filled out during the home walk-throughs.

4.2.1 Energy Consumption and Cost Patterns

An important component of the audit form was the section asking residents to provide the energy consumption and costs from energy bills from the past year. This section was important for the investigation of what time of the year energy use peaks on the island and also for the comparison of the consumption of different occupancy groups and locations. Due to a lack of resident and project team preparation, the group was only able to compile complete twelve month histories of consumption and energy costs for two of the audited homes. The two residences that provided this information were a three-person home in Guaynabo and a four-person home in Carolina.

Using the collected data, the group computed the total energy consumption and costs per residence as well as the energy consumption and costs per capita. *Figure 25* shows the comparison of the total energy consumption between the two audited homes. *Figure 26* shows the comparison of the total consumption per capita between the two audited homes. Graphs displaying the comparison between the energy costs per household versus per capita of all of the audited homes are presented in the Appendix G.

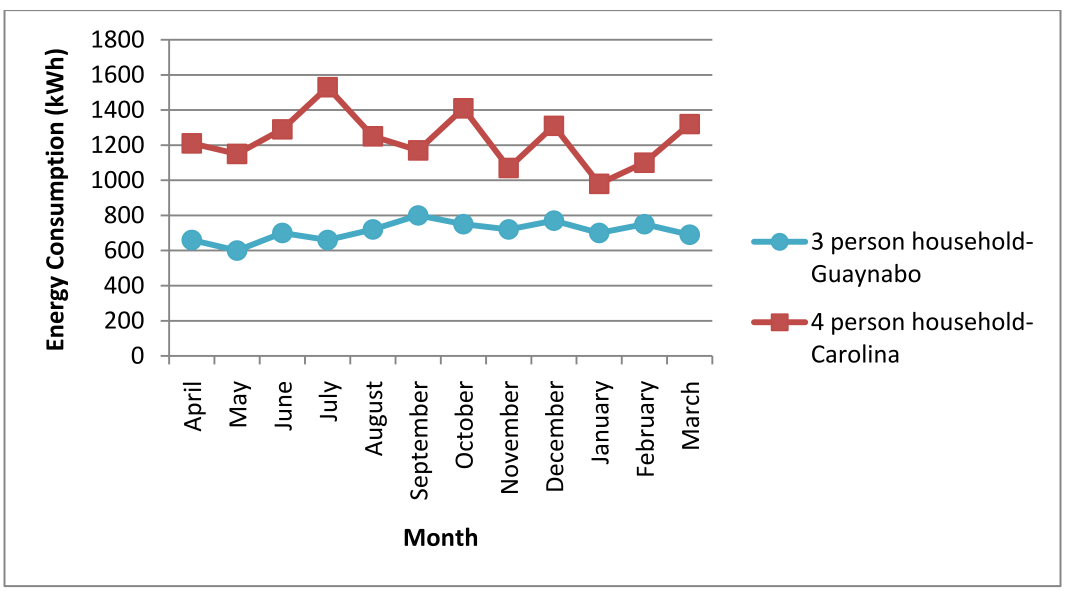

Figure 25: Distribution of Annual Energy Consumption per Household

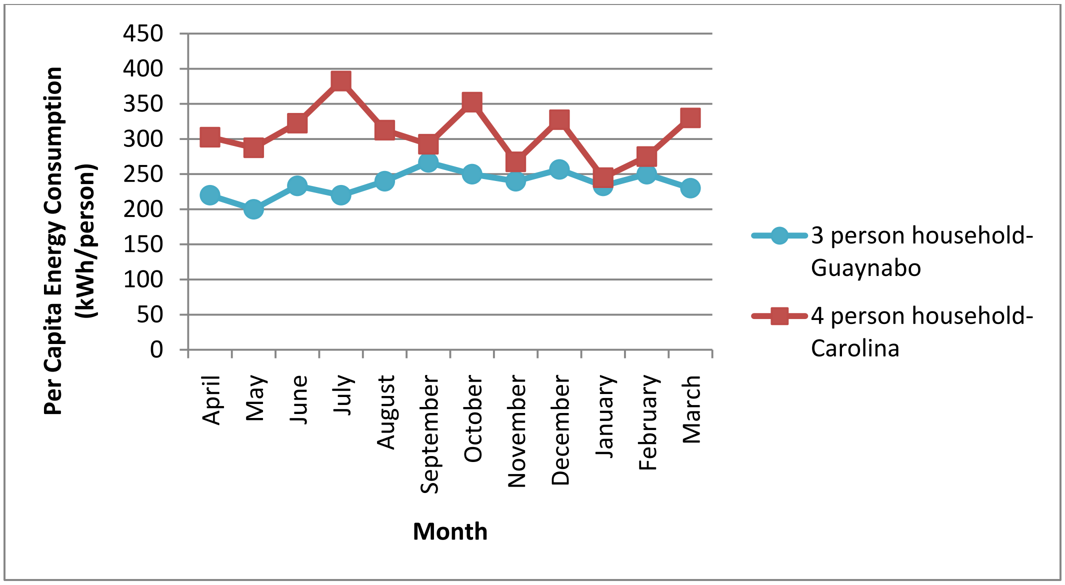

Figure 26: Distribution of Annual Energy Consumption per Capita

In analyzing these figures, it is noted that the four-person household in Carolina consumed more total and per capita energy during the last 12 months than the three-person residence in Guaynabo. *Figure 26* suggests that during certain months, energy consumption per capita is very similar. Additional audits may indicate whether energy use per capita is constant with regards to household size and location. Another observation is that the energy consumption for the four-person household in Carolina reached its maximum during the month of July, whereas the three-person household in Guaynabo had one of its lowest consuming months of the year at this time. These differences in consumption may be due to such factors as warmer outside temperatures, as well as potential family vacations during this period. A larger interview portion within the audit discussing behavioral factors such as vacations may confirm this result. Residents implementing energy conservation methods during this time of peak energy use may also explain this result. The residence in Guaynabo showed more constant energy consumption throughout the last 12 months than the residence in Carolina, which may be due to heightened energy use awareness. Given the small size of this data set, it cannot be determined whether these results represent trends with the overall population of Puerto Rico.

4.2.2 Energy Conservation Techniques

The awareness and implementation of energy conservation techniques were assessed by a brief series of questions that were asked to the homeowner during the auditing process. Although 100% of the residents receiving the walk-through audits reported having high electric bills, it became evident that the residents took many different efforts to make their residences more efficient. All of the residents reported that they only use air conditioning at night since the residences were empty during normal working hours. They also reported trying to cool their house with natural ventilation, utilizing open windows and doors as an alternative to running air conditioning units, as frequently as possible. In addition to these facts, 100% of the residents interviewed reported efforts to use natural lighting as much as possible and limit the time their water heaters were on. Other important findings included resident interest in learning how to further conserve energy and a desire to replace existing appliances with ENERGY STAR products. This willingness to learn and desire to conserve energy is important to note while developing energy conservation recommendations.

4.2.3 Reinforcement of Survey Results and Additional Insights

Survey results pertaining to residence size, energy use, and energy conservation awareness were compared to the five audits that the group completed. In regards to household size, it was observed that four out of five of the audited homes fell within the 1,000 to 2,000 square foot range, the range in which the majority of the survey results fell into, considered average. A majority of the audited homes contained only one electric water heater, which was also the case with the survey results. The owners of the audited residences also seemed very conscious of energy saving alternatives, which is likely due to bias of the audited population; however, this awareness also matches the results that were seen in the survey results. For example, all of the audited residences used some if not all fluorescent lighting, which supports the majority reported by the surveyed population. Though the results for the typical model for a Puerto Rican residence could not be confirmed with the limited number of audits completed, the project team believes that a larger sample population receiving the audits would support the survey data.

The audit provided for a few additional insights about the structure of the residences. The original audit form developed for this project took into account many of the structural components impacting residence efficiency. Although this section was almost completely removed, several insights about residence maintenance and energy efficiency were obtained that were not examined in the survey. In general, the older the residence, the more likely there were to be window, door, or moisture issues. For example, the audited residence that was built in 1975 reported to have window, moisture, and other outstanding issues; whereas, the residence built in 1995 reported no current structural issues. However, taking into account the limited data set, comparisons between structural issues and typical energy consumption show no obvious trend.

Although not included in the audit form, the age of residents likely play a role in typical household consumption. For example, the two four-person households in Guaynabo received the same walk-through audit with very different results. The first household had four adults and the second household had two adults and two young children. The first household had significantly higher energy consumption than the household with two small children. These trends were not confirmed with other audits but should be examined with further data collection.

Chapter 5: Recommendations for Energy Conservation Improvements

The survey results and walk-through audits provided the group with sufficient data to formulate recommendations for the AAE and citizens of Puerto Rico regarding energy conservation improvements. It is important to note that these recommendations are based strictly on the survey and audit results and may not be applicable for the entire Puerto Rican population. The following topics are recommendations based on identified areas where Puerto Ricans can improve their energy consumption.

1. Renovate residences, particularly those built prior to 1990, with additional energy efficient appliances and construction techniques.
2. Decrease residential laundry machine and dryer use by performing less loads of laundry and using communal Laundromats and air drying clothing when possible.
3. Reduce the amount of time air conditioners, as well as other household appliances, are used by setting timers that control the duration of use.
4. Replace traditional incandescent light bulbs with energy efficient, compact fluorescent light bulbs.
5. Turn off electric water heaters when they are not in use. Invest in solar water heaters which are energy efficient and gaining popularity on the island of Puerto Rico.
6. Increase the number of ENERGY STAR appliances used within residences.
7. Unplug household appliances that are not in use.

5.1 Household Renovations

An important aspect to home energy efficiency often overlooked is construction techniques. These can be anything from building materials to the windows and doors used. ENERGY STAR is a government run program that not only takes into account appliances but also the construction of the home. The data suggests that 42% of the survey population has a residence constructed prior to the 1990s, which is relevant because ENERGY STAR standards were not introduces until the early 1990s. There are many things that could be inspected for inefficiencies. Window seals can be a significant problem if they are not sealed correctly. The broken seal can allow air conditioning to seep out causing the machine to overwork and consume more energy. Residences should be inspected for inefficiencies once the new building codes have been implemented.

5.2 Laundry Machine and Dryer Use

The data from the survey suggests that 47% of the survey population machine washes four or more loads of laundry per week. In the average household appliance consumption chart located in Appendix A, it is shown that laundry washing machines are the fourth highest consumer of energy while the laundry dryer is the highest overall. One recommendation the group can make from this data is for residents to try to perform fewer loads of laundry per week. This may be accomplished by combining loads so that the machines are being efficiently used. Residents may also take advantage of communal laundry services, such as Laundromats, to reduce energy consumption within their own residences.

5.3 Controlled Timers to Limit Appliance and Air Conditioner Use

The data collected in both our survey and energy walk-through audit helped the project team determine that timers, which regulate energy to appliances based upon the time of day, are not commonly used. Timers are a method of reducing energy consumption by automatically actuating the flow of electricity to an appliance or lighting fixture. This can reduce energy by cutting back on energy that is wasted when unused appliances are left on even though they may not be actively in use. Along the same lines, the use of motion sensors for lighting applications can reduce energy consumption by only illuminating a given space when a person or animal is present. Reducing the amount of wasted energy should be a primary focus of residents in an effort to reduce their energy consumption. In particular, the survey results show that 64% of the surveyed population runs their air conditioners between 7 to 12 hours per day, a rather high percentage. The use of regulated timers for air conditioners may decrease this percentage of the population who run their air conditioner for extended periods of time.

5.4 Replacement of Incandescent Light Bulbs with CFLs

Implementing the use of compact fluorescent lamps is a common technique used to conserve energy. The collected data suggests that this is already a popular technique among residents in Puerto Rico as a large majority of the residents surveyed and all of the residents audited reported using them. Benefits of using CFLs besides energy savings include significantly larger lamp life and they are easy to find anywhere that sells light bulbs.

5.5 Water Heater Use

Electric water heaters are a major consumer of energy in a household. Conventional water heaters heat water and store it in a tank so that hot water is available on command. If a home's water heater is not properly insulated the water will cool over the course of the day and the water heater will run to maintain the water temperature. This is a significant area where energy can be conserved. As our energy walk-throughs and surveys have confirmed, most homes are vacant during typical work hours. Simply turning off the power to the water heater when it is idle will conserve the energy that would be used to maintain water temperature when no one is home. Due to the amount of energy required to heat water, smart use of conventional water heaters has the potential to save residents money on their electric bill. Line water heaters heat water as it passes through the unit such that the heater is only in operation when hot water is in demand. This alleviates the problem of a cyclically running conventional unit.

Solar water heaters provide a viable alternative to conventional or line water heaters. The survey results showed that solar water heaters are fairly common in Puerto Rico. Hopefully in the future the AAE will have the resources to promote solar water heating. Government incentives in the past have been shown to encourage residents to participate in similar "greener" practices.

5.6 ENERGY STAR Appliances

The survey results showed that the majority of the survey population has awareness of the ENERGY STAR program. Even though 94% of the population (noted as potentially biased) is aware of ENERGY STAR, the AAE should continue its efforts to promote ENERGY STAR appliances and construction techniques. There may not be as high percentage of Puerto Ricans outside of the group of people who were surveyed who are aware of ENERGY STAR. In examining the survey results, it is seen that 59% of the population have three or fewer ENERGY STAR appliances in their homes. This data was supported by the walk-through audits in that a majority of the homes only consisted of a few ENERGY STAR appliances, if any at all. This trend indicates a potential area for improvements in appliances within Puerto Rican homes. A recommendation for residents would be to invest in ENERGY STAR products when replacing appliances to experience the long-term benefits that ENERGY STAR appliances have on reducing overall energy consumption and costs.

5.7 Unplugging of Household Appliances

Unplugging appliances when not in use is a quick, easy way to conserve energy. Approximately half the people surveyed reported using this technique and it was observed while performing the walk-through audits that some residents actually do use this technique within their residence. Although not the most convenient conservation method, unplugging appliances when not in use saves the residence additional energy consumption without investing additional money for a product or service.

Chapter 6: Conclusion

Due to the expenses associated with fossil fuel electricity generation, it is important that residents of Puerto Rico are aware of methods that can increase the energy efficiency of their residences. There are many simple techniques that can reduce residential energy consumption. The methods outlined in Chapter 3 and the analysis and results discussed in Chapter 4 helped identify how energy is used within residences. These steps allowed the group to develop measures that can be taken to reduce energy use and develop a basis for future research.

The background information obtained from our literature review provided insight into the technical and social aspects pertaining to the project. Topics of interest within the literature review included: energy use and consumption, related energy simulations, energy use assessment techniques, and the capability of alternative energy and energy saving practices in Puerto Rico.

Due to potential language barriers, invasion of privacy concerns, legal barriers, and time constraints, the methods were developed with care, undergoing several revisions before being beta tested and used in this study. The thorough process of development ensured that the methodology would effectively complete the objectives while protecting the rights and privacy of the Puerto Rican residents and the AAE. Key components of our methodological procedure consisted of sending out an online survey to residents throughout Puerto Rico and performing walk-through energy audits on select residences to determine current energy use, and developing the recommendations for residential energy conservation.

The results and analysis of the collected data provided insights into some of the many factors within a residence influencing energy consumption. These insights were used to develop energy conservation recommendations suitable to be presented to the residents of Puerto Rico. They are also relevant in regards to developing stronger surveys and audits which may include additional questions about demographics and daily appliance use for future research.

Although the mailing lists used for the online survey and the selected residences to receive walk-through audits introduced a bias to this study, the project team believes that the population that took part in this study falls within the class of residents most likely to modify their residences and behaviors to be more energy efficient. This is due to the team's knowledge of their professional job tracks, since the surveys were sent to professional societies. It is likely that these people are knowledgeable and can afford to modify their residences to conserve energy. As noted in the discussion of the survey results, these people are aware and impacted by their energy costs enough to make modifications that will decrease their energy bill.

This project had significance to each team member as well as the AAE. The project team benefited from this project through the experience of working outside the classroom on a "real world" problem as a team within a professional agency. Although results may be biased and inconclusive, the study provides the AAE with a foundation to further their research, paramount towards their goal of developing a home energy rating system for Puerto Rico.

Chapter 7: Recommendations for Future Projects

There were a few difficulties the group ran into throughout the IQP process in Puerto Rico. Many of these difficulties the group experienced may have been avoided had the group known more about the politics involved with working within a government agency during the PQP process. In regards to the study, it is important to note the impact of the surveys and audits on the success of the project. Both of these means of data collection were helpful for the group in the analysis of the current energy consumption patterns in Puerto Rican residences. The AAE's overall goal for this project was to investigate important energy characteristics to develop a home energy rating system similar to the RESNET system. Continuing to survey and audit the general public to create a standard for all Puerto Rican homes is vital toward this ultimate goal.

One problem the group experienced was with the survey bias. The survey may be biased due to the mailing lists that were provided by the AAE. The mailing lists, which were comprised of The College of Engineers and Surveyors of Puerto Rico and The Manufacturer's Association of Puerto Rico, likely middle-upper working class individuals, did not ideally represent the entire Puerto Rican community. One way future project teams can combat this problem is with face-to-face surveys. Not only would this allow the group to reach a broader range of the population, but also will likely provide a higher return rate. Face to face surveys may also eliminate the bias by reaching more residents who may not own computers. Another potential way future teams can overcome this problem would be to generate a survey that would then be mailed to different residential areas, also reaching a more diverse population. Finally, the future teams should include more questions regarding demographics. For example, it would be useful to understand whether the person being surveyed is the one paying the electric bill.

In order to attain all of the information needed to develop an accurate typical residential energy model, a larger time frame is needed to perform energy audits within the residences. If approved by the AAE, the group believes that using the survey to advertise the audits would be a useful way to determine which residences receive audits. As implemented in the group's survey, the resident would be asked to email the project team in order to be considered and it also noted that their survey results would be kept anonymous in this procedure. A larger number of samples, as well as samples from low, average, and high income households would allow for a broader spectrum of data and consequently less biased results. Utilizing a more thorough interview portion, asking more demographic questions such as ages of those in the household, as wells as determining periods where energy use is lower due to certain events such as vacations is also recommended for future work. Audit form development and training with a professional auditor may also be useful in continuation of this research. This could allow for more thorough audits, taking into account structural components such as poorly sealed windows and inefficient venting.

Due to time constraints, the group did not have the opportunity to perform a complete statistical analysis of the data that was collected from the survey results. This is, in part, due to the way the questions in the survey were developed. Although weighted averages may be used on some of the questions, the use of open ended ranges, such as “4+”, and ranges that are overly large makes it difficult to do an accurate analysis. This could be remedied by refining the survey answer bins. The development of an accurate home energy rating system will depend upon examination of this data. Specific statistical information that is important includes the mean, median, and standard deviation of the collected results for each survey question. Comprehensive statistical data from this study, in conjunction with future residential energy projects, would provide sufficient input values to develop the simulations used in creating an energy efficiency rating system for Puerto Rico.

In the future, energy simulations could prove to be useful to the AAE in assessing the current energy use on the island and determining which energy conservation techniques may have the largest impact in Puerto Rico. With a well developed model of a typical home, using information from both this project and a series of professional full home audits, assumptions can be made to create an energy simulation that is applicable to residences in Puerto Rico. The initial simulation could verify current energy consumption as a reference for future data analysis. From this point, the simulation assumptions can be varied to account for the implementation of different energy conservation techniques; these simulation results can be compared to the initial results to see how certain energy conservation techniques can improve home efficiency. Although a thorough energy simulation does take a notable initial investment of time and money, the insight provided by such energy simulations would be invaluable to the AAE and island of Puerto Rico.

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Appendices

Appendix A: Related Background Information

A.1 Demographics – Residents and Families in Puerto Rico

An understanding of the demographic nature of the population is beneficial to understanding the energy consumption patterns. For this study, average annual salaries, family sizes, and levels of education of low-income, middle-class, and upper-class citizens of Puerto Rico were reviewed.

A.1.1 Economic Status Comparison between Continental U.S. and Puerto Rico

The economic status of Puerto Rican citizens varies from residents of the continental United States, which may account for the differences in household energy use. In 2008, the median income for a residence in Miami, Florida (which has the same climate zone and similar energy concerns as Puerto Rico) was $29,151, as published by the United States Census; comparatively, the median income for a household in San Juan, Puerto Rico was $23,879 (census.gov, 2009). This difference in median income levels is relevant in assessing the difference in lifestyles and residential energy use between the continental United States and Puerto Rico.

A.1.2 Low-Income Residences

The average size of families in Puerto Rico has changed drastically in the last fifty years. According to the International Federal Housing and Planning guidelines,

> In 1940 Puerto Rico had a population of 1,869,255 inhabitants; the average family consisted of 5.5 members and a population growth of 1.94. In 2008, the island has a population of nearly 4 million with an average family of 3.5 members and a population growth of 0.01 (ifhp.org, 2008).

For low-income residences, this study evaluated single and multi-family homes, and small apartments including Section 8 housing units. Low-income residences are difficult to define. In San Juan, Puerto Rico, "affordable housing is defined as housing units whose sale price falls in the range between $80,000 and $180,000" (ifhp.org, 2008). "Affordable housing" may not necessarily always be low-income housing and is defined to be, "choices for very low-income residences…allowing families to choose privately owned rental housing" (hud.gov, 2010). Section 8 housing units are addressed as several of them are located around San Juan. Low-income residences are found throughout Puerto Rico; however, 31% of the island's population resides in San Juan which is the primary focus of this study.

In San Juan, the average annual income ranges from $4,850 to $9,150 in the lowest 30% of the population, $8,100 to $15,250 in the category considered "very low income," and $12,950 to $24,400 in the category labeled "low income" (huduser.org, 2009). A significant majority of these residents did not attain higher education, such as attending college.

A.1.3 Middle and Upper-Income Residences

The Puerto Rican middle class is rather difficult to define. The residents in this class comprise a smaller portion of the overall population in relation to the low-income residents.

Puerto Rico Median Income (Source: census.gov, 2009)

Family Size	Income Estimate	Margin of Error
2	$16,643	+/- 497
3	$21,640	+/-736
4	$25,404	+/-1,064
5	$24,838	+/- 1,815
6	$21,042	+/- 3,559
7+	$23,145	+/- 3,796
Average	$20,425	+/- 414

The majority of the upper and middle classes are comprised of those individuals who received higher education. The middle class citizens earn incomes ranging between $35,000 and $100,000. This range contains 45.7% of the population according to the US Census data in 2007. Finally, the upper class citizens earn incomes greater than $100,000, which includes 11.3% of the families in Puerto Rico (census.gov, 2009). It is important to understand the income ranges of all three societal classes before analyzing data collected from the residents.

A.1.4 Problems Associated with Puerto Rican Residences

Puerto Rico is struggling through an economic recession that has led to an increased price of energy on the island. Although energy prices continue to increase, residents are still using the same amount of energy in their daily lives. In an interview with Jan Maduro, from the Puerto Rico Energy Affairs Administration, the project team learned that typical residences in Puerto Rico are equipped with everyday electrical appliances, including laundry washers and dryers, standard lighting devices, air conditioners, computers, televisions, and assorted kitchen appliances (i.e. refrigerators and microwave ovens) (J. Maduro, personal communication January 29, 2009). Due to the low fluctuating temperatures in Puerto Rico's climate zone, heaters are not needed and dishwashers are considered a luxury.

Many Puerto Rican homes lack energy efficient devices, such as ENERGY STAR appliances. This causes problems with increased energy usage and high energy prices. Electricity costs are a significant issue for residents of Puerto Rico, particularly the low-income population. As the cost of energy increases due to the rising price of foreign oil and Puerto Rico's dependence on this energy source, many citizens are struggling to afford the cost of energy (L.M. Jimenez, personal communication December 14, 2009).

A.2 Average Household Appliance Consumption

The average consumption of particular household appliances was researched for this study and is shown in the following table (from New Hampshire).

Typical Wattage of Household Appliances (Sources: psnh.com and flatheadelectric.com)	
Appliance	**Typical Wattage (kWh)**
Laundry Dryer	4,900
Water Heater (8 hrs of use)	4,500
Air Conditioner (10,000 BTU)	1,000
Laundry Washer	500
Refrigerator	500
Television 32-inch	130
Laptop Computer	75

Appendix B: Online Survey Form

Puerto Rico Residential Energy Survey

Please note: All information in this survey is confidential, anonymous and fully optional. This survey is to be used for the Puerto Rico Residential Energy Project sponsored by the AAE and Worcester Polytechnic Institute in Worcester, Massachusetts.

Household Information

1. What is your zip code?

2. What is the approximate size of your residence? (In square feet)

- Small (less than 1000)
- Average (1000 to 2000)
- Above average (greater than 2000)
- I do not know

3. When was your home built?

- Prior to 1960
- 1960s
- 1970s
- 1980s
- 1990s
- 2000 or more recently
- I do not know

4. How many people permanently live in your residence? Please include students living at college or boarding high school.

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- Other:

5. On average, how many hours a week do you work away from home?

- Less than 10
- 10 to 30
- 31 to 39
- 40
- More than 40

Household Energy Use

6. How many air conditioners are regularly operating in your residence? If you answer "I do not have one" please skip to question 10

- 1
- 2
- 3
- 4 or more
- I do not have one

7. What type of air conditioner do you have?

- Window Unit
- Split Unit
- Both
- Other:

8. How many hours is your air conditioner turned on each day?

- Less than 2
- 2 to 6
- 7 to 12
- 12 or more
- I do not know

9. What temperature is your air conditioner usually set to?

- Very Cold (less than 67°F/19.4°C)
- Cold (67°F/19°C to 70°F/21.1°C))
- Mild (71°F/20.6°C to 73°F/22.7°C)
- Warm (above 73°F/22.7°C)

10. Do you operate a clothes drying machine in your residence?

- Yes, electric
- Yes, gas
- No
- I do not know
- Other:

11. How many loads of laundry do you machine wash a week in your residence?

- Less than 1
- 1
- 2
- 3
- 4 or more
- I do not do laundry within my residence

12. How many water heaters do you have?

- 1
- 2
- 3 or more
- I do not know
- I do not have one

13. What type of water heater do you have?

- Solar
- Electric
- Gas
- Line
- I do not know
- Other:

14. How many of the following appliances are operating within your residence?

	1	2	3+	I do not have one
Televisions	○	○	○	○
Computers	○	○	○	○
Refrigerators	○	○	○	○

Energy Conservation Techniques

15. Have you heard of ENERGYSTAR?

- ○ Yes
- ○ No

16. How many ENERGYSTAR appliances do you own?

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4 or more
- ○ I do not know

17. Are you aware that ENERGYSTAR appliances can reduce your electricity bill?

- ○ Yes
- ○ No

18. Have you implemented any of the following energy conservation methods suggested by the AAE?

- ☐ Unplugging/turning off appliances not in use
- ☐ Clean and replace air conditioner filters
- ☐ Paint rooms light colors and use curtains or canvas awnings to keep rooms cooler
- ☐ Use a solar water heater or turn off heater when not in use
- ☐ Keep pots and pans covered and oven closed as to not lose heat while cooking
- ☐ Air dry clothing instead of using a dryer and iron
- ☐ Use compact fluorescent light bulbs
- ☐ Use timers on appliances such as lights, televisions, and waterheaters
- ☐ Use ENERGYSTAR rated appliances
- ☐ Other: ______

Electricity Bill

19. What is the current energy consumption of your residence? (In kilowatt hours (Kwh) based upon last month's PREPA bill)

- Less than 300
- 300 to 800
- 801 to 1300
- More than 1300
- I do not know

20. What is your approximate monthly energy bill payment? (In dollars based upon last months PREPA bill?)

- Less than $80
- $80-200
- $201-350
- More than $350
- I do not know

Interested in a FREE Energy Walk Through?

If you would be interested in a free energy walk thru your home, please send an email with your contact information to: pr.energy2010@gmail.com Please note: auditing hours will be from 9am to 4pm Monday through Friday or by appointment

Submit

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Appendix C: RESNET Comprehensive Home Assessment Audit Form

Company Logo

Home Performance Assessment

[Enter Company Name]

HOME PERFORMANCE WITH ENERGY STAR

Customer Name: ______ Customer Phone Number (h): ______
Customer Address: ______ Customer Phone Number (w): ______
City, State, Zip: ______ Customer Email: ______
Inspection Date: ______ Home Performance Analyst: ______

Homeowner Interview and Consumption History

How Did They Hear? Article Referral Web Search Radio Regional Program Nat'l Program Other: ______
Type of Home: Colonial Dutch Colonial Cape Split Level Duplex Town/Rowhouse: End Unit? Y N Other: ______
Foundation/Basement: Slab on Grade Basement: Conditioned / Unconditioned / Partially Conditioned Crawlspace: Vented / Unvented

Year Built/Age: ______ Roof Age/Cond: ___ / ___ Fireplace/Wood Stove: Yes No Pool Open/Close Dts: ___ / ___
Yrs in Home: ______ Siding Type/Cond: ___ / ___ Confirm no fires for HPA: Yes No Pool Pump Hrs/Day: ______
Occupants: ______ Heating Fuel: ______ DHW Fuel: ______ Pool Pump HP/Watts: ______
Additions: ______ Back-Up Elect Heat: Yes No Pool Htg Fuel: ______ Pool Area (L x W): ______

Top Homeowner Priorities / Concerns / Motivations
1. ______
2. ______

Energy Consumption History

Month	Electric kWh	Electric $	Fossil Units	Fossil $
Jan				
Feb				
Mar				
Apr				
May				
Jun				
Jul				
Aug				
Sep				
Oct				
Nov				
Dec				
Total				

Customer Needs / Complaints

Interviewee:			Details
1. High Bills	Yes	No	
2. Drafts	Yes	No	
3. Hot/Cold Rooms	Yes	No	
4. Air Quality Problems	Yes	No	
5. Odors	Yes	No	
6. Moisture Issues	Yes	No	
7. Water Leaks	Yes	No	
8. Window Problems	Yes	No	
9. Door Problems	Yes	No	
10. Moisture Issues/Damage	Yes	No	
11. Excessive D[illegible]	Yes	No	
12. ______	Yes	No	
13. ______	Yes	No	

Appliances, Lighting, T-Stats, Other

Major Appliances	Estar	Size	Age	Model Number / Condition / Usage
Refrigerator 1				
Refrigerator 2				
Freezer				
Dishwasher				
Washing Machine				
Dehumidifier				
Dryer	NA			
Cooking Range / Oven	NA			
______				
______				

Lighting	# Bulbs	% CFL
High Use (>3 hrs/day)		
Other		

Room Air Conditioners
# of Units: ______ Age: ______
Estar: Yes No EER (if known): ______

Dryer Fuel: ______ Vented Properly? Yes No
CO Detectors: ______ Per Floor: Yes No
Smoke Detectors: ______ Per Floor: Yes No

Thermostats: ______ Programmable? Yes No Heating Setpoint: ______ Cooling Setpoint: ______
Bathrooms: ______ # of Bath Fans: ______ Vented Properly? Yes No Low-Flow Showerheads?: Yes No

Building Info

Conditioned Sqft: ______ Outside Temp: ______ Knob & Tube Wiring?: Yes No
Avg Ceiling Hgt: ______ House Orientation: ______ Whole House Fan?: Yes No
Number of Stories: ______ Roof Vent Type(s): ______ Unvented Space Htrs/Fireplaces?: Yes No
Volume Cond Space: ______ Roof Vents Are: OK Inadequate Balloon Framing?: Yes No
Moisture/Other Issues: ______

Attic Insulation

Attic Flats and Slopes	R-Val	Insulation Type	Insulation Amount	Cav Size (e.g. 2x6)	Open or Enclosed	Surface Area (sqft.)	# Rec. Cans	Attic Access	Attic Fan	Notes
				2 x	Open Encl					
				2 x	Open Encl					
				2 x	Open Encl					
				2 x	Open Encl					
				2 x	Open Encl					

Attic Kneewall/Vertical	R-Value	Insulation Type	Insulation Amount	Cav. Size (e.g. 2x4)	Surface Area (sqft.)	Notes
				2 x		
				2 x		
				2 x		
				2 x		

Customer Name: ______ [Company Name Here] Inspection Date: ______

EXAMPLE FORM

EXAMPLE FORM

Wall Insulation

Sidewall Sections	R-Value	Insulation Type.	Insulation Amount	Cav. Size (e.g. 2x4)	Surface Area (sqft.)	Notes
				2 x		
				2 x		
				2 x		
				2 x		

Basement/Crawl Insul.

Basement Walls & Sill Plate	Conditioned?	Insulation Location	R-Value	Wall Height	Depth Bel. Grd.	Sqft or Linear Ft	Notes
	Yes No						
	Yes No						
Sill Plate	Yes No						

Crawlspace	Access	Vented?	Insulation Location	R-Value	Wall Height	Depth Bel. Grd.	Sqft Walls	Sqft Floor	Notes
	Gd Pr	Yes No							
	Gd Pr	Yes No							

Windows/Doors

Windows (Select typical size) — Exterior Doors

Orientation	Qty.	Panes	Storms?	Frame	Condition	Typ Size	%Wall	Location	Type	Condition	Insulated	Air Seal Needed
		1 2 3	Yes No	W V M	Gd Fair Pr	x			Wd Mtl	Gd Fair Pr	Yes No	WX Sweep Clk
		1 2 3	Yes No	W V M	Gd Fair Pr	x			Wd Mtl	Gd Fair Pr	Yes No	WX Sweep Clk
		1 2 3	Yes No	W V M	Gd Fair Pr	x			Wd Mtl	Gd Fair Pr	Yes No	WX Sweep Clk
		1 2 3	Yes No	W V M	Gd Fair Pr	x			Wd Mtl	Gd Fair Pr	Yes No	WX Sweep Clk

Air Leakage

Blower Door Test: ________ CFM50 / ACH (circle one) Ventilation Standard: ________ CFM50 / ACH (circle one) Excess Air Leakage: ________ CFM50 / ACH (circle one)

Air Leakage Locations (check all that apply)

Attic Wire/Pipe Penetrations		Recessed Lights		Crawlspace		Porch Roof		Notes:
Kneewalls / Attic Stairs		Chimney / Flues		Windows		Garage Wall		
Pocket Doors / Attic Access		Basement Penetrations		Cantilevers		Garage Ceil		
Drop Soffits		Sill Plate		Bay Window		Cl. Closets		

Heating and Cooling Systems

	Heating System 1	Heating System 2		Cooling System 1	Cooling System 2
Brand:			Brand:		
Type (Furnace, Boiler, HP):			Type (AC, HP):		
Fuel:			Model #:		
Model #:			Tonnage:		
Age / Cond.:			Age / Cond.:		
Input/Output BTU's:			SEER / EER:		
Eff. Rating (AFUE, HSPF):			Air Handl Loc.:		
Steady State Eff.:			Coils Cond.:		
Location (Bsmt, Gar):			Cond. Out Unit:		
			Loc. Outside Unit:		

Freq. of Servicing: ________ Filter Clean: Yes No Condensate Line Issues: ________

Humidifier: Yes No Flue Vent Issues: ________

Combustion Related Tests

	Flue Gas CO ppm	Natural Draft	Worst Case Draft	Natural Spillage	Worst Case Spillage
Heating System 1:		pa	Pass Fail	Pass Fail	Pass Fail
Heating System 2:		pa	Pass Fail	Pass Fail	Pass Fail
DHW System:		pa	Pass Fail	Pass Fail	Pass Fail
Other:		pa	Pass Fail	Pass Fail	Pass Fail

	Fuel	CO ppm	Vent Out?
Oven 1:			Yes No
Oven 2:			Yes No

	Kitchen	Main Living	Other
Ambient CO 1:			
Ambient CO 2:			

	Ambient CO	Base Pressure	Worst Case Pressure	Final (Net) CAZ Depressurization	CAZ Standard	Pass or Fail
CAZ 1:						P F
CAZ 2:						P F

Fuel Leaks: ☐ None detected ☐ Leak(s) detected - see below

DHW

Location: Conditioned Basement / Utility Room / Closet Unconditioned Basement / Utility Room Garage Crawlspace Other: ________

Type:		Age/Condition:		Model #:		Tank Wrapped?:	Yes No
Gallons:		Output BTU:		Temp Setting:		Press. Relief Valve?:	Yes No
Fuel:		Efficiency (EF):		Flue Issues:			

Distribution System and Notes

% Ducts in Uncond Attic: ________

% Ducts in Uncond Bsmt/Crawl: ________ Duct Leakage Test (optional): Duct Blast BD Subtract Delta Q Press Pan

Duct / Pipe Insulation: R - ________ Duct Test Result (use note field for press pan): ________

Visual Leakage: Low Med High Airflow Test Result (optional): ________

Notes Field:

Pressure Pan Test (Duct WRT House)

House WRT Duct Location: ________ pa

Location	Pa	Location	Pa
1		10	
2		11	
3		12	
4		13	
5		14	
6		15	
7		16	
8		17	
9		18	

Appendix D: Original Audit Form

Puerto Rico Residential Energy Audit

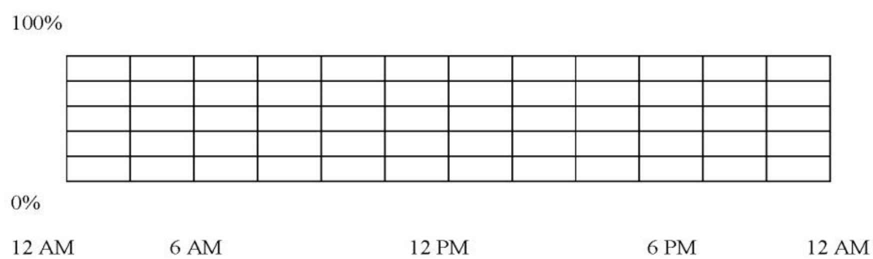
Names of persons performing audit: ____

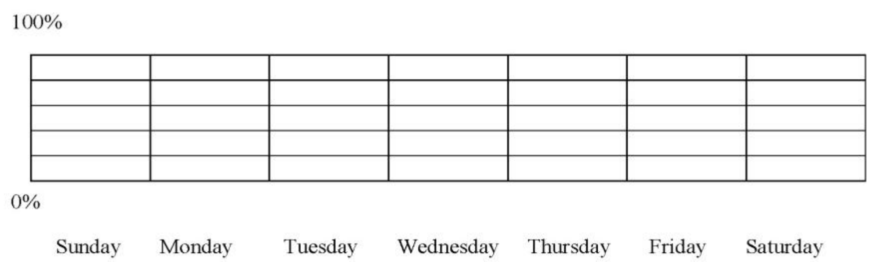
Date: __________ Time: __________ Outside Temp: ________________________

Household information

Household size: ____________

Daily Occupancy Profile:





Resident Interview

1. High Bills Yes No ______________________________
2. Drafts Yes No ______________________________
3. Air Quality Problems Yes No ______________________________
4. Odors Yes No ______________________________
5. Moisture Leaks Yes No ______________________________
6. Window Problems Yes No ______________________________
7. Door Problems Yes No ______________________________
8. Moisture Issues Yes No ______________________________

Current Conservation Techniques Implemented:

____

Energy Consumption History

Month	KWh	Cost
January		
February		
March		
April		
May		
June		
July		
August		
September		
October		
November		
December		
Total Year		

Building Information

Address: ____________________________

House Orientation: ____________________

Owner: Private Landlord

If landlord, please include name of contact

____

Residence size (in square feet): __________

Date of construction: _________________

Last building update occurred:

>5 years ago 5-10 years ago 10+ years ago

Please provide specific renovation dates if known:

____

What types of restorations/renovations have been done on building?

____

____

Type of residence: ____________________

How many floors if a house: ___________

Average ceiling height: ________________

Foundation material: __________________

Building material: ____________________

Does house have balloon framing? Yes No

Roof vent type (s): __________________________

Are roof vents adequate? Yes No

# of Bathrooms __________

Condition of ventilation:

Good Fair Poor Uninsulated

Are there low-flow showerheads? Yes No

Does the house have any other issues? Yes No

Roof

Location				
Insulation Type				
R-Value				
Insulation Amount				
Cav size	2 x	2 x	2 x	2 x
Open or Enclosed				
Surface Area (ft2)				
Notes				

Exterior Wall

Location				
Insulation Type				
R-Value				
Insulation Amount				
Cav Size	2 x	2 x	2 x	2 x
Surface Area (ft2)				
Notes				

Windows

Orientation					
Qty.					
Panes	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3
Storms?	Yes No	Yes No	Yes No	Yes No	Yes No
Frame	W V M	W V M	W V M	W V M	W V M
Condition	Gd Fair Pr	Gd Fair Pr	Gd Fair Pr	Gd Fair Pr	Gd Fair Pr
Typ. Size	x	x	x	x	x
% wall					

Doors

Location	Type	Condition	Insulated	Air Seal Needed
	Wd Mb	Gd Fair Pr	Yes No	WX Sweep Clk
	Wd Mb	Gd Fair Pr	Yes No	WX Sweep Clk
	Wd Mb	Gd Fair Pr	Yes No	WX Sweep Clk
	Wd Mb	Gd Fair Pr	Yes No	WX Sweep Clk

Cooling

Conditioned area of home (sq. ft.) ______________________

# of Thermostats ________

Are thermostats programmable? Yes No

Is there air conditioning? Yes No

What type of air conditioning in residence?
Window Units Split None

Frequency of cleaning: ________________

Filter clean: Yes No

Condensate line issues: _______________

Humidifier: Yes No

Unit #				
Brand				
Type				
Model #				
Size				
Age				
Condition	Gd Fair Pr	Gd Fair Pr	Gd Fair Pr	Gd Fair Pr
SEER/EER				
Setting				
Location				
ENERGYSTAR	Yes No	Yes No	Yes No	Yes No

Number of fans: ____________________

Notes (types, location) ________________

Water Heater

Unit		
Size		
Fuel		
Age		
Condition		
Output BTU		
Efficiency		
Location		
Temp. Setting		

Is the water heater wrapped? Yes No

Is there a pressure relief valve? Yes No

Lighting

Number of fixtures: ___________________

Number of Incandescent lightbulbs: ______

Comments: (Ex: Timers, switches, motion sensors)
____
____

Other Appliances

	ENERGYSTAR	Size	Age	Condition/Usage
Refrigerator 1				
Refrigerator 2				
Freezer				
Dishwasher				
Washing Machine				
Dehumidifier				
Dryer				
Cooking Range/Oven				
Television				
Computer				

Dryer Fuel: Gas Electric

Dryer Ventilation Condition: Good Fair Needs Improvement Uninsulated

CO Detectors ________

Smoke Detectors _____

Appendix E: Working Walk-Through Audit Form

Puerto Rico Residential Energy Audit

Names of persons performing audit: ____

Date: ____________ Time: ____________ Outside Temp: ______________________________

Building Information

Address: ____________________________

Owner: Private Landlord

If landlord, please include name of contact

____

Residence size (in square feet): __________

Date of construction: _________________

Last building update occurred:

>5 years 5-10 years 10+ years

Please provide specific renovation dates if known:

____

What types of restorations/renovations have been done on building?

____

____

Type of residence: ____________________

How many floors if a house: ___________

Average ceiling height: ________________

# of Bathrooms __________

# of Bedrooms ___________

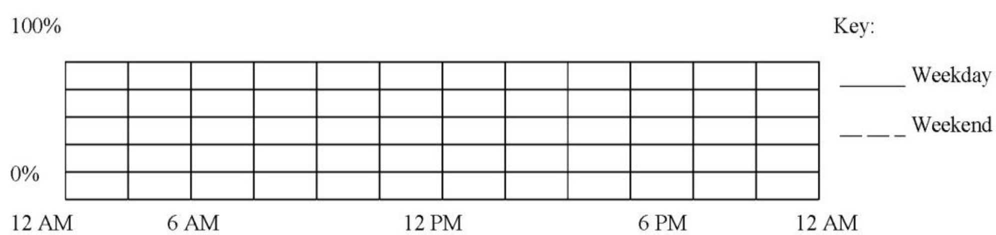
Are there low-flow showerheads? Yes No

Does the house have any other issues? Yes No

Household information

Household size: _______________

Daily Occupancy Profile:



Resident Interview

1. High Bills	Yes	No	________________________________
2. Window Problems	Yes	No	________________________________
3. Door Problems	Yes	No	________________________________
4. Moisture Issues	Yes	No	________________________________

Do you implement any of the following energy conservation techniques?

1. Turn off and unplug appliances when not in use	Yes	No	______________________
2. Cool your house with natural ventilation	Yes	No	______________________
3. Use curtains or canvas to keep the sun out of rooms	Yes	No	______________________
4. Turn off your water heater when not in use	Yes	No	______________________
5. Use lightning fixtures only when necessary	Yes	No	______________________
6. Purchase ENERGYSTAR appliances	Yes	No	______________________
7. Use pots with lids while cooking	Yes	No	______________________
8. Use a pressure cooker or microwave	Yes	No	______________________
9. Use glass instead of metal while baking	Yes	No	______________________
10. Limit use of dryers by drying clothing outside	Yes	No	______________________

Energy Consumption History

Month	KWh	Cost
January		
February		
March		
April		
May		
June		
July		
August		
September		
October		
November		
December		
Total Year		

Cooling

Conditioned area of home (sq. ft.)
____

# of Thermostats ________

Are thermostats programmable? Yes No

Is there air conditioning? Yes No

# of Window Units _______

# of Split Units __________

Frequency of cleaning: _________________

Filter clean: Yes No

Condensate line issues: ________________

Dehumidifier: Yes No

Unit #				
Brand				
Type				
Output BTU				
Age				
Condition	Gd Fair Pr	Gd Fair Pr	Gd Fair Pr	Gd Fair Pr
Frequency of use				
Setting				
Location				
ENERGYSTAR	Yes No	Yes No	Yes No	Yes No

Number of fans: _____________________

Notes (types, location) _______________________

Water Heater

Unit #		
Size		
Fuel		
Age		
Condition		
Output BTU		
Location		
Temp. Setting		

Is the water heater wrapped? Yes No

Lighting

Number of fixtures: ___________________

Number of fluorescent lightbulbs: ______

Comments: (Ex: Timers, switches, motion sensors)
____
____

Other Appliances

	ENERGYSTAR	Size	Age	Condition	Frequency of Use	Notes
Refrigerator 1	Yes No			Good Fair Poor		
Refrigerator 2	Yes No			Good Fair Poor		
Freezer	Yes No			Good Fair Poor		
Dishwasher	Yes No			Good Fair Poor		
Washing Machine	Yes No			Good Fair Poor		
Dehumidifier	Yes No			Good Fair Poor		
Dryer	Yes No			Good Fair Poor		
Cooking Range/Oven	Yes No			Good Fair Poor		
Television	Yes No			Good Fair Poor		
Computer	Yes No			Good Fair Poor		

Dryer Fuel: Gas Electric

Appendix F: Survey Results

F.1 Combined Data

Household Information

2. Size of residence	Number of Answers	Percentage
Small (less than 1000 sq. ft)	81	9.17%
Average (1000 to 2000 sq. ft)	484	54.81%
Above Average (greater than 2000 sq. ft)	293	33.18%
I do not know	25	2.83%
	883	
3. When home was built	**Number of Answers**	**Percentage**
Prior to 1960	35	3.96%
1960s	86	9.74%
1970s	131	14.84%
1980s	116	13.14%
1990s	202	22.88%
2000 or more recently	294	33.30%
I do not know	19	2.15%
	883	
4. Occupancy	**Number of Answers**	**Percentage**
1	74	8.38%
2	254	28.77%
3	199	22.54%
4	249	28.20%
5	86	9.74%
6	17	1.93%
7	3	0.34%
8	1	0.11%
Other	0	0.00%
	883	
5. Average hours per week that person works away from home	**Number of Answers**	**Percentage**
Less than 10	115	13.05%
10 to 30	85	9.65%
31 to 39	54	6.13%
40	171	19.41%
More than 40	456	51.76%
	881	

Energy Use

6. Number of operating air conditioners in residence	Number of Answers	Percentage
1	310	35.11%
2	225	25.48%
3	138	15.63%
4 or more	73	8.27%
I do not have one	137	15.52%
	883	

7. Type of air conditioner	**Number of Answers**	**Percentage**
Window unit	210	28.15%
Split unit	395	52.95%
Both	120	16.09%
Other	21	2.82%
	746	
8. Hours air conditioner operates each day	**Number of Answers**	**Percentage**
Less than 2	95	12.73%
2 to 6	145	19.44%
7 to 12	476	63.81%
12 or more	30	4.02%
I do not know	0	0.00%
	746	
9. Typical air conditioner temperature	**Number of Answers**	**Percentage**
Very cold (less than 67 □F/19.4 □C)	101	13.54%
Cold (67 □F/19 □C to 70 □F/21.1 □C)	308	41.29%
Mild (71 □F/20.6 □C to 73 □F/22.7 □C)	279	37.40%
Warm (above 73 □F/22.7 □C)	58	7.77%
	746	
10. Clothes drying machine	**Number of Answers**	**Percentage**
Yes, electric	564	63.87%
Yes, gas	162	18.35%
No	148	16.76%
I do not know	8	0.91%
Other	1	0.11%
	883	
11. Loads of laundry machine washed per week in residence	**Number of Answers**	**Percentage**
Less than 1	60	6.88%
1	9	1.03%
2	154	17.66%
3	211	24.20%
4 or more	412	47.25%
I do not do laundry within my residence	26	2.98%
	872	
12. Number of water heaters	**Number of Answers**	**Percentage**
1	802	91.34%
2	41	4.67%
3 or more	2	0.23%
I do not know	0	0.00%
I do not have one	33	3.76%
	878	
13. Type of water heater	**Number of Answers**	**Percentage**
Solar	242	27.56%
Electric	428	48.75%
Gas	17	1.94%
Line	181	20.62%
I do not know	10	1.14%
Other	0	0.00%

	878	
14. Number of televisions	**Number of Answers**	**Percentage**
1	258	29.38%
2	396	45.10%
3+	216	24.60%
I do not have one	8	0.91%
	878	
14. Number of computers	**Number of Answers**	**Percentage**
1	420	56.07%
2	283	37.78%
3+	24	3.20%
I do not have one	22	2.94%
	749	
14. Number of refrigerators	**Number of Answers**	**Percentage**
1	645	77.62%
2	154	18.53%
3+	32	3.85%
I do not have one	0	0.00%
	831	

Energy Conservation Techniques

15. Heard of ENERGY STAR	**Number of Answers**	**Percentage**
Yes	825	94.18%
No	51	5.82%
	876	
16. Number of ENERGY STAR appliances	**Number of Answers**	**Percentage**
0	109	13.09%
1	120	14.41%
2	155	18.61%
3	112	13.45%
4 or more	233	27.97%
I do not know	104	12.48%
	833	
17. Aware ENERGY STAR appliances can reduce electricity bill	**Number of Answers**	**Percentage**
Yes	814	93.56%
No	56	6.44%
	870	
18. Implemented any conservation methods	**Number of Answers**	**Percentage**
Unplugging/turning off appliances not in use		
Clean and replace air conditioner filters		
Paint rooms light colors and use curtains		
Use a solar water heater or turn off water heater while not in use		
Keep pots and pans covered and oven closed		
Air dry clothing instead of using a dryer		
Use compact fluorescent light bulbs		
Use timers on appliances such as lights, televisions, etc.		
Use ENERGY STAR rated appliances		
Other		

19. Current energy consumption in residence	Number of Answers	Percentage
Less than 300	106	12.57%
300 to 800	293	34.76%
801 to 1300	201	23.84%
More than 1300	82	9.73%
I do not know	161	19.10%
	843	
20. Approximate monthly energy bill	**Number of Answers**	**Percentage**
Less than $80	109	12.47%
$80-200	465	53.20%
$201-350	229	26.20%
More than $350	65	7.44%
I do not know	6	0.69%
	874	

F.2 Low Occupancy Data

Household Information

2. Size of residence	Number of Answers	Percentage
Small (less than 1000 sq. ft)	48	14.63%
Average (1000 to 2000 sq. ft)	180	54.88%
Above Average (greater than 2000 sq. ft)	92	28.05%
I do not know	8	2.44%
	328	
3. When home was built	**Number of Answers**	**Percentage**
Prior to 1960	17	5.18%
1960s	32	9.76%
1970s	61	18.60%
1980s	34	10.37%
1990s	62	18.90%
2000 or more recently	116	35.37%
I do not know	6	1.83%
	328	
4. Occupancy	**Number of Answers**	**Percentage**
1	74	22.56%
2	254	77.44%
3	0	0.00%
4	0	0.00%
5	0	0.00%
6	0	0.00%
7	0	0.00%
8	0	0.00%
Other	0	0.00%
	328	
5. Average hours per week that person works away from home	**Number of Answers**	**Percentage**
Less than 10	57	17.38%
10 to 30	42	12.80%
31 to 39	15	4.57%
40	53	16.16%
More than 40	161	49.09%
	328	

Energy Use

6. Number of operating air conditioners in residence	Number of Answers	Percentage
1	201	61.28%
2	62	18.90%
3	6	1.83%
4 or more	14	4.27%
I do not have one	45	13.72%
	328	
7. Type of air conditioner	**Number of Answers**	**Percentage**
Window unit	98	34.63%
Split unit	131	46.29%

Both	36	12.72%
Other	18	6.36%
	283	
8. Hours air conditioner operates each day	**Number of Answers**	**Percentage**
Less than 2	53	18.60%
2 to 6	59	20.70%
7 to 12	162	56.84%
12 or more	10	3.51%
I do not know	1	0.35%
	285	
9. Typical air conditioner temperature	**Number of Answers**	**Percentage**
Very cold (less than 67 □F/19.4 □C)	42	14.95%
Cold (67 □F/19 □C to 70 □F/21.1 □C)	105	37.37%
Mild (71 □F/20.6 □C to 73 □F/22.7 □C)	108	38.43%
Warm (above 73 □F/22.7 □C)	26	9.25%
	281	
10. Clothes drying machine	**Number of Answers**	**Percentage**
Yes, electric	220	67.07%
Yes, gas	34	10.37%
No	74	22.56%
I do not know	0	0.00%
Other	0	0.00%
	328	
11. Loads of laundry machine washed per week in residence	**Number of Answers**	**Percentage**
Less than 1	49	15.12%
1	7	2.16%
2	90	27.78%
3	82	25.31%
4 or more	76	23.46%
I do not do laundry within my residence	20	6.17%
	324	
12. Number of water heaters	**Number of Answers**	**Percentage**
1	294	89.91%
2	14	4.28%
3 or more	1	0.31%
I do not know	0	0.00%
I do not have one	18	5.50%
	327	
13. Type of water heater	**Number of Answers**	**Percentage**
Solar	68	20.99%
Electric	169	52.16%
Gas	3	0.93%
Line	81	25.00%
I do not know	3	0.93%
Other	0	0.00%
	324	
14. Number of televisions	**Number of Answers**	**Percentage**
1	152	46.77%

2	139	42.77%
3+	28	8.62%
I do not have one	6	1.85%
	325	
14. Number of computers	**Number of Answers**	**Percentage**
1	181	58.20%
2	104	33.44%
3+	13	4.18%
I do not have one	13	4.18%
	311	
14. Number of refrigerators	**Number of Answers**	**Percentage**
1	260	84.14%
2	39	12.62%
3+	10	3.24%
I do not have one	0	0.00%
	309	

Energy Conservation Techniques

15. Heard of ENERGY STAR	**Number of Answers**	**Percentage**
Yes	300	92.31%
No	25	7.69%
	325	
16. Number of ENERGY STAR appliances	**Number of Answers**	**Percentage**
0	48	15.95%
1	50	16.61%
2	63	20.93%
3	35	11.63%
4 or more	65	21.59%
I do not know	40	13.29%
	301	
17. Aware ENERGY STAR appliances can reduce electricity bill	**Number of Answers**	**Percentage**
Yes	303	92.38%
No	25	7.62%
	328	
19. Current energy consumption in residence	**Number of Answers**	**Percentage**
Less than 300	67	21.68%
300 to 800	118	38.19%
801 to 1300	45	14.56%
More than 1300	16	5.18%
I do not know	63	20.39%
	309	
20. Approximate monthly energy bill	**Number of Answers**	**Percentage**
Less than $80	74	22.63%
$80-200	188	57.49%
$201-350	50	15.29%
More than $350	13	3.98%
I do not know	2	0.61%

F.3 Average Occupancy Data

Household Information

2. Size of residence	**Number of Answers**	**Percentage**
Small (less than 1000 sq. ft)	31	6.92%
Average (1000 to 2000 sq. ft)	247	55.13%
Above Average (greater than 2000 sq. ft)	157	35.04%
I do not know	13	2.90%
	448	
3. When home was built	**Number of Answers**	**Percentage**
Prior to 1960	9	2.01%
1960s	43	9.60%
1970s	58	12.95%
1980s	70	15.63%
1990s	111	24.78%
2000 or more recently	148	33.04%
I do not know	9	2.01%
	448	
4. Occupancy	**Number of Answers**	**Percentage**
1	0	0.00%
2	0	0.00%
3	200	44.64%
4	248	55.36%
5	0	0.00%
6	0	0.00%
7	0	0.00%
8	0	0.00%
Other	0	0.00%
	448	
5. Average hours per week that person works away from home	**Number of Answers**	**Percentage**
Less than 10	38	8.64%
10 to 30	50	11.36%
31 to 39	30	6.82%
40	90	20.45%
More than 40	232	52.73%
	440	

Energy Use

6. Number of operating air conditioners in residence	**Number of Answers**	**Percentage**
1	92	20.54%
2	146	32.59%
3	105	23.44%
4 or more	32	7.14%
I do not have one	73	16.29%
	448	
7. Type of air conditioner	**Number of Answers**	**Percentage**
Window unit	97	25.87%
Split unit	205	54.67%

Both	67	17.87%
Other	6	1.60%
	375	
8. Hours air conditioner operates each day	**Number of Answers**	**Percentage**
Less than 2	32	8.53%
2 to 6	65	17.33%
7 to 12	235	62.67%
12 or more	17	4.53%
I do not know	26	6.93%
	375	
9. Typical air conditioner temperature	**Number of Answers**	**Percentage**
Very cold (less than 67 □F/19.4 □C)	48	12.80%
Cold (67 □F/19 □C to 70 □F/21.1 □C)	160	42.67%
Mild (71 □F/20.6 □C to 73 □F/22.7 □C)	130	34.67%
Warm (above 73 □F/22.7 □C)	37	9.87%
	375	
10. Clothes drying machine	**Number of Answers**	**Percentage**
Yes, electric	278	62.05%
Yes, gas	104	23.21%
No	64	14.29%
I do not know	2	0.45%
Other	0	0.00%
	448	
11. Loads of laundry machine washed per week in residence	**Number of Answers**	**Percentage**
Less than 1	10	2.23%
1	1	0.22%
2	59	13.17%
3	109	24.33%
4 or more	259	57.81%
I do not do laundry within my residence	10	2.23%
	448	
12. Number of water heaters	**Number of Answers**	**Percentage**
1	412	92.58%
2	21	4.72%
3 or more	0	0.00%
I do not know	0	0.00%
I do not have one	12	2.70%
	445	
13. Type of water heater	**Number of Answers**	**Percentage**
Solar	136	30.43%
Electric	212	47.43%
Gas	9	2.01%
Line	85	19.02%
I do not know	5	1.12%
Other	0	0.00%
14. Number of televisions	**Number of Answers**	**Percentage**
1	91	20.40%
2	210	47.09%

3+	143	32.06%
I do not have one	2	0.45%
	446	
14. Number of computers	**Number of Answers**	**Percentage**
1	206	47.47%
2	142	32.72%
3+	77	17.74%
I do not have one	9	2.07%
	434	
14. Number of refrigerators	**Number of Answers**	**Percentage**
1	322	76.67%
2	84	20.00%
3+	14	3.33%
I do not have one	0	0.00%
	420	

Energy Conservation Techniques

15. Heard of ENERGY STAR	Number of Answers	Percentage
Yes	424	95.28%
No	21	4.72%
	445	
16. Number of ENERGY STAR appliances	**Number of Answers**	**Percentage**
0	53	11.91%
1	61	13.71%
2	81	18.20%
3	67	15.06%
4 or more	129	28.99%
I do not know	54	12.13%
	445	
17. Aware ENERGY STAR appliances can reduce electricity bill	**Number of Answers**	**Percentage**
Yes	417	92.26%
No	35	7.74%
	452	
19. Current energy consumption in residence	**Number of Answers**	**Percentage**
Less than 300	35	7.92%
300 to 800	155	35.07%
801 to 1300	127	28.73%
More than 1300	36	8.14%
I do not know	89	20.14%
	442	
20. Approximate monthly energy bill	**Number of Answers**	**Percentage**
Less than $80	34	8.04%
$80-200	218	51.54%
$201-350	137	32.39%
More than $350	31	7.33%
I do not know	3	0.71%

F.4 High Occupancy Data

Household Information

2. Size of residence	**Number of Answers**	**Percentage**
Small (less than 1000 sq. ft)	3	2.80%
Average (1000 to 2000 sq. ft)	57	53.27%
Above Average (greater than 2000 sq. ft)	44	41.12%
I do not know	3	2.80%
	107	
3. When home was built	**Number of Answers**	**Percentage**
Prior to 1960	8	7.48%
1960s	11	10.28%
1970s	12	11.21%
1980s	12	11.21%
1990s	30	28.04%
2000 or more recently	30	28.04%
I do not know	4	3.74%
	107	
4. Occupancy	**Number or Answers**	**Percentage**
1	0	0.00%
2	0	0.00%
3	0	0.00%
4	0	0.00%
5	86	80.37%
6	17	15.89%
7	3	2.80%
8	1	0.93%
Other	0	0.00%
	107	
5. Average hours per week that person works away from home	**Number of Answers**	**Percentage**
Less than 10	8	7.77%
10 to 30	5	4.85%
31 to 39	9	8.74%
40	18	17.48%
More than 40	63	61.17%
	103	
Energy Use		
6. Number of operating air conditioners in residence	**Number of Answers**	**Percentage**
1	17	15.89%
2	17	15.89%
3	27	25.23%
4 or more	27	25.23%
I do not have one	19	17.76%
	107	
7. Type of air conditioner	**Number of Answers**	**Percentage**
Window unit	13	14.77%
Split unit	54	61.36%

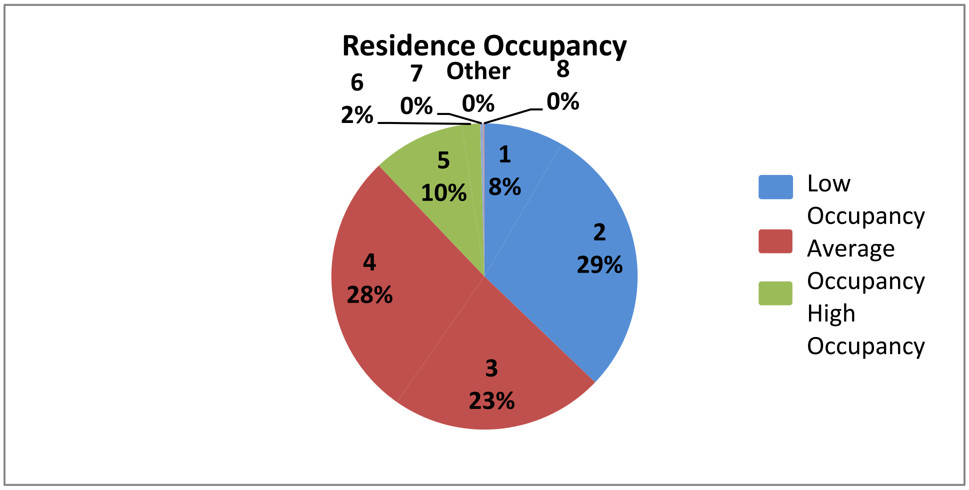
Both	17	19.32%
Other	4	4.55%
	88	
8. Hours air conditioner operates each day	**Number of Answers**	**Percentage**
Less than 2	8	8.99%
2 to 6	15	16.85%
7 to 12	61	68.54%
12 or more	3	3.37%
I do not know	2	2.25%
	89	
9. Typical air conditioner temperature	**Number of Answers**	**Percentage**
Very cold (less than 67 □F/19.4 □C)	11	12.50%
Cold (67 □F/19 □C to 70 □F/21.1 □C)	42	47.73%
Mild (71 □F/20.6 □C to 73 □F/22.7 □C)	31	35.23%
Warm (above 73 □F/22.7 □C)	4	4.55%
	88	
10. Clothes drying machine	**Number of Answers**	**Percentage**
Yes, electric	66	61.68%
Yes, gas	26	24.30%
No	13	12.15%
I do not know	1	0.93%
Other	1	0.93%
	107	
11. Loads of laundry machine washed per week in residence	**Number of Answers**	**Percentage**
Less than 1	1	0.93%
1	1	0.93%
2	5	4.67%
3	20	18.69%
4 or more	77	71.96%
I do not do laundry within my residence	3	2.80%
	107	
12. Number of water heaters	**Number of Answers**	**Percentage**
1	97	90.65%
2	6	5.61%
3 or more	1	0.93%
I do not know	0	0.00%
I do not have one	3	2.80%
	107	
13. Type of water heater	**Number of Answers**	**Percentage**
Solar	38	35.51%
Electric	47	43.93%
Gas	5	4.67%
Line	15	14.02%
I do not know	2	1.87%
Other	0	0.00%
	107	
14. Number of televisions	**Number of Answers**	**Percentage**
1	15	14.02%

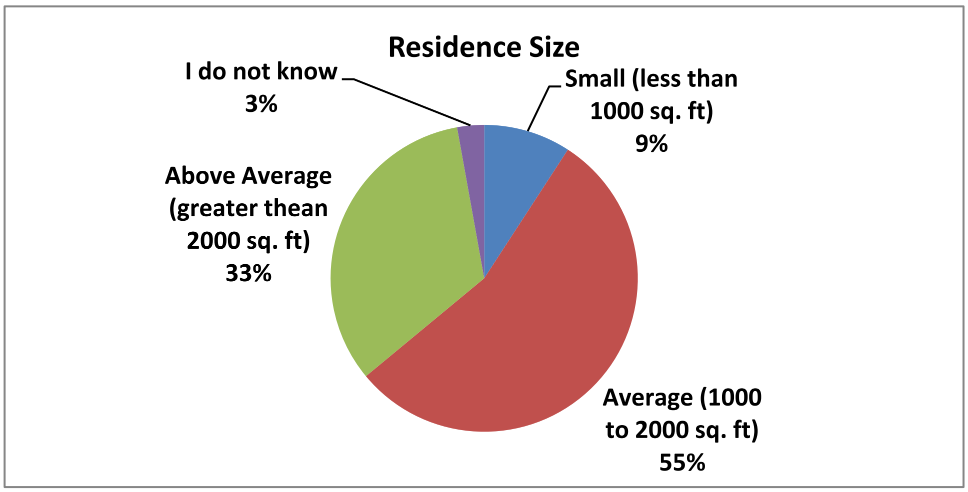
2	47	43.93%
3+	45	42.06%
I do not have one	107	
14. Number of computers	**Number of Answers**	**Percentage**
1	33	31.73%
2	37	35.58%
3+	34	32.69%
I do not have one	0	0.00%
	104	
14. Number of refrigerators	**Number of Answers**	**Percentage**
1	63	61.76%
2	31	30.39%
3+	8	7.84%
I do not have one	0	0.00%
	102	

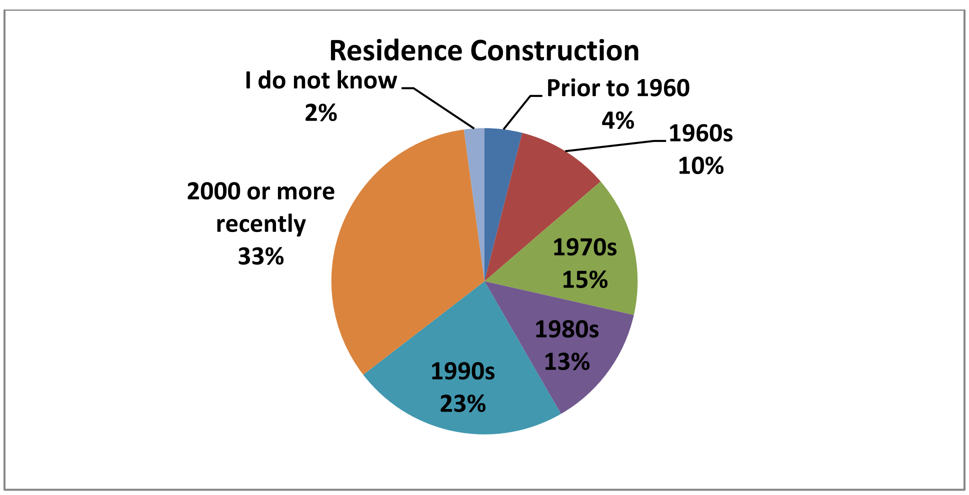
Energy Conservation Techniques

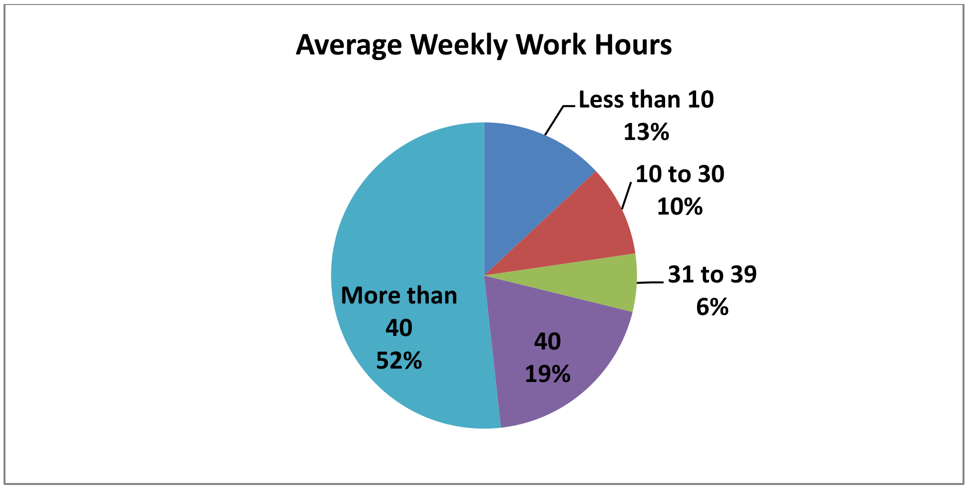
15. Heard of ENERGY STAR	**Number of Answers**	**Percentage**
Yes	90	95.74%
No	4	4.26%
	94	
16. Number of ENERGY STAR appliances	**Number of Answers**	**Percentage**
0	12	11.65%
1	12	11.65%
2	20	19.42%
3	17	16.50%
4 or more	35	33.98%
I do not know	7	6.80%
	103	
17. Aware ENERGY STAR appliances can reduce electricity bill	**Number of Answers**	**Percentage**
Yes	102	95.33%
No	5	4.67%
	107	
19. Current energy consumption in residence	**Number of Answers**	**Percentage**
Less than 300	5	4.81%
300 to 800	26	25.00%
801 to 1300	32	30.77%
More than 1300	25	24.04%
I do not know	16	15.38%
	104	
20. Approximate monthly energy bill	**Number of Answers**	**Percentage**
Less than $80	0	0.00%
$80-200	45	42.45%
$201-350	40	37.74%
More than $350	20	18.87%
I do not know	1	0.94%
	106	

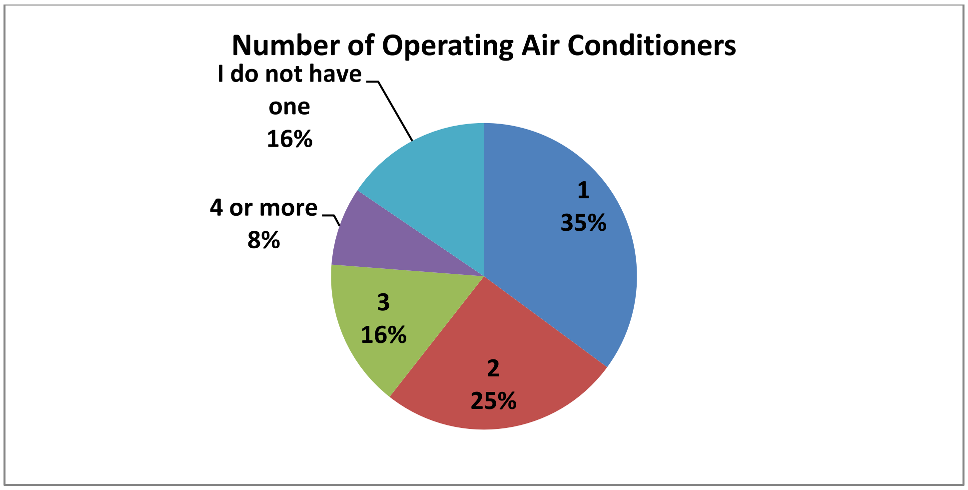
F.5 Combined Data Charts

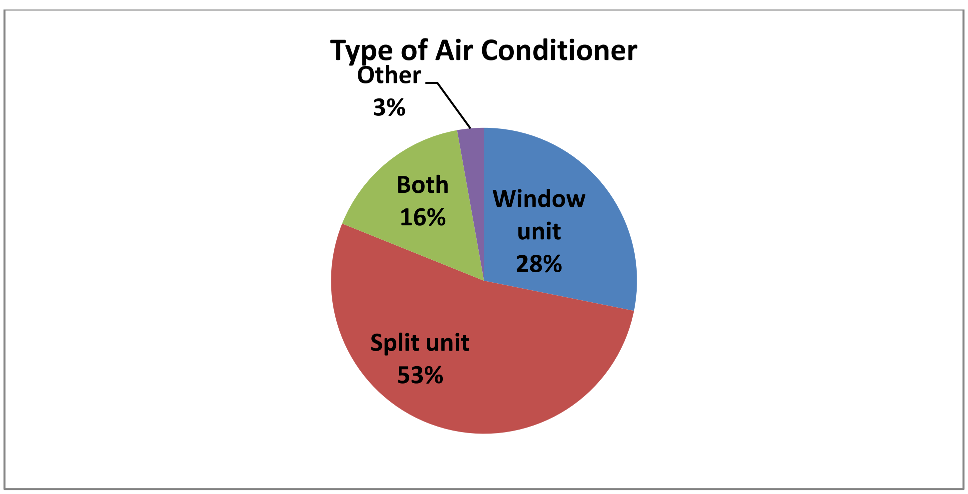


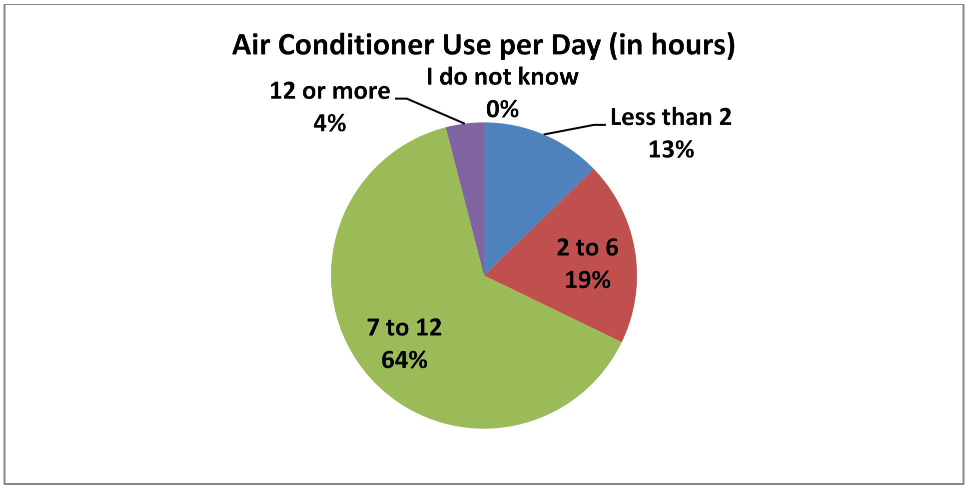


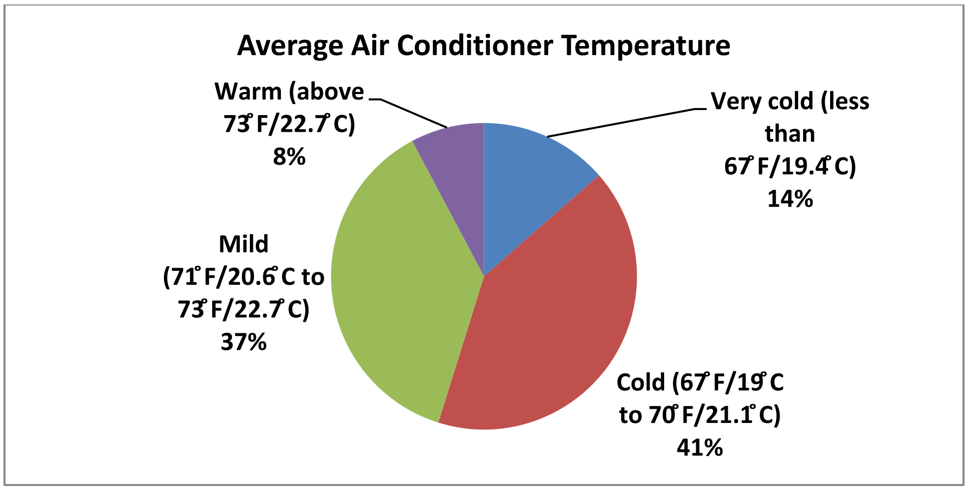


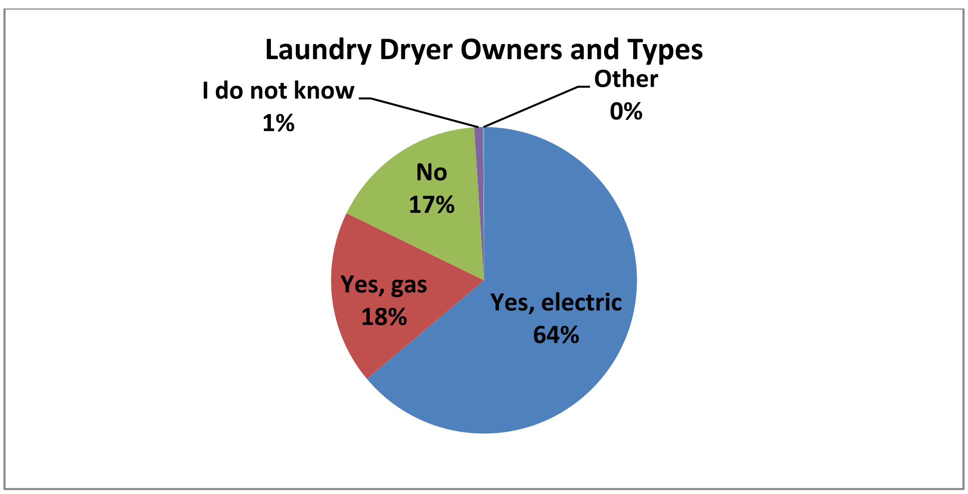

Average Weekly Work Hours
Less than 10
13%
10 to 30
10%
31 to 39
6%
40
19%
More than
40
52%

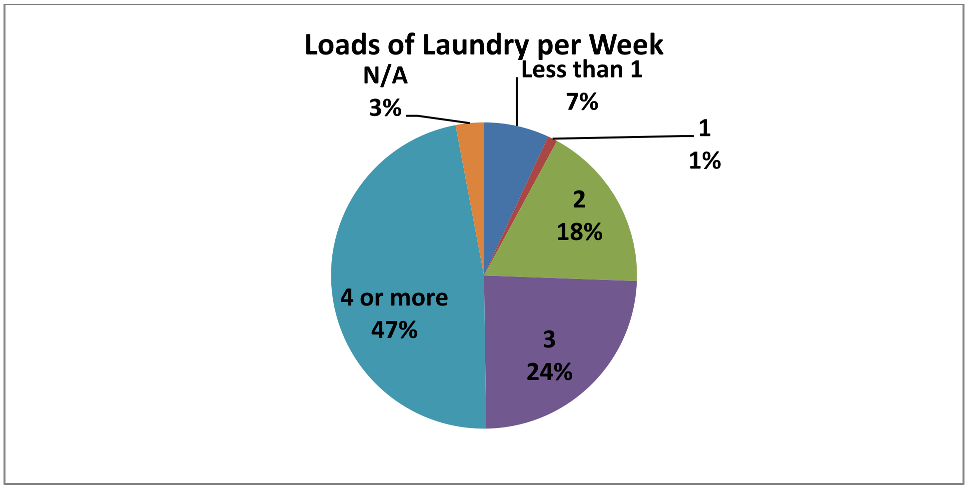

Number of Operating Air Conditioners
I do not have
one
16%
1
35%
2
25%
3
16%
4 or more
8%

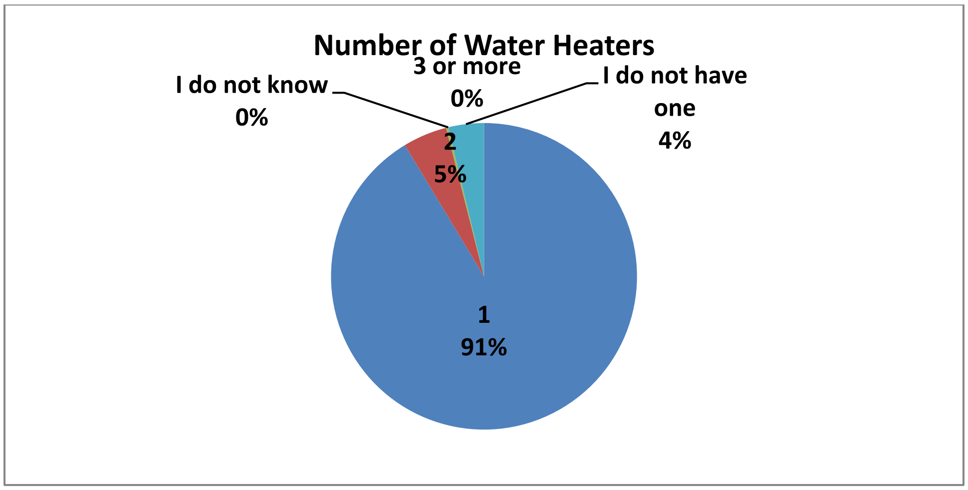

Type of Air Conditioner
Other
3%
Window
unit
28%
Split unit
53%
Both
16%

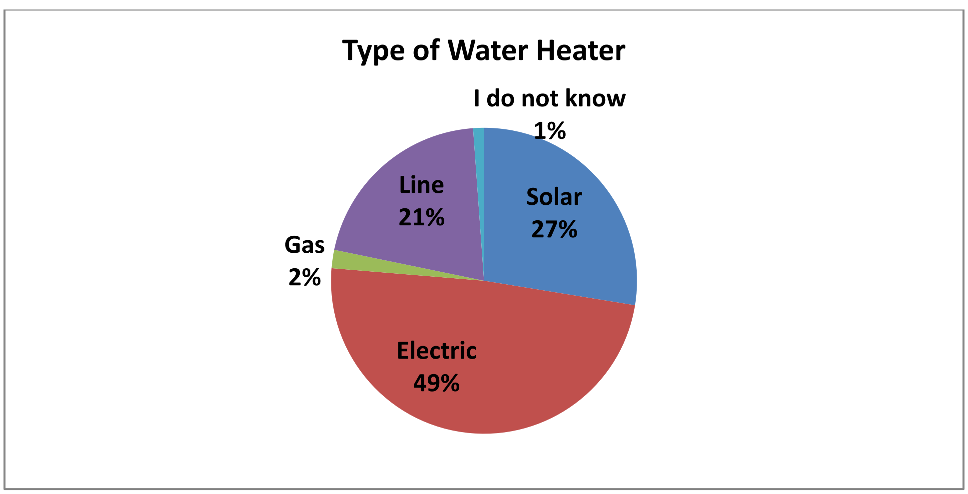

Air Conditioner Use per Day (in hours)
I do not know 0%
12 or more 4%
Less than 2 13%
2 to 6 19%
7 to 12 64%

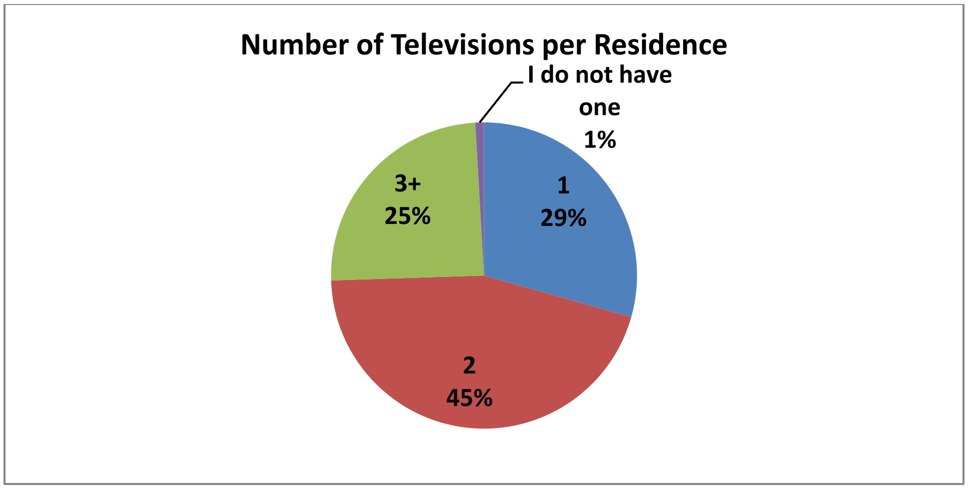

Average Air Conditioner Temperature
Warm (above 73̊F/22.7̊C) 8%
Very cold (less than 67̊F/19.4̊C) 14%
Mild (71̊F/20.6̊C to 73̊F/22.7̊C) 37%
Cold (67̊F/19̊C to 70̊F/21.1̊C) 41%

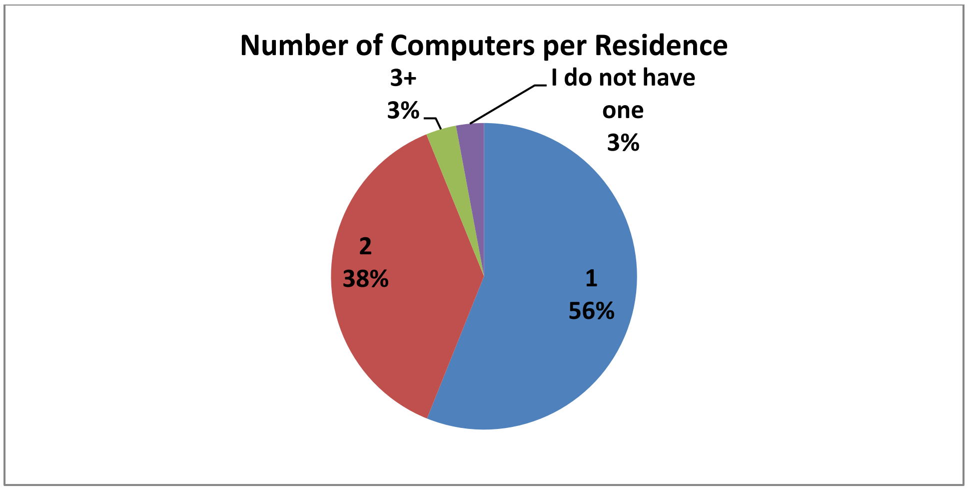

Laundry Dryer Owners and Types
I do not know 1%
Other 0%
No 17%
Yes, gas 18%
Yes, electric 64%

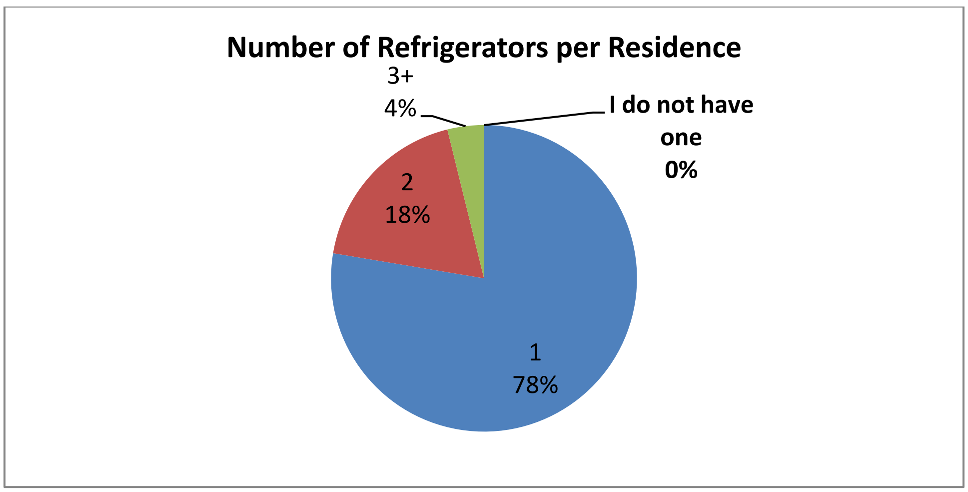

Loads of Laundry per Week
N/A
3%
Less than 1
7%
1
1%
2
18%
4 or more
47%
3
24%


Number of Water Heaters
I do not know
0%
3 or more
0%
I do not have
one
4%
2
5%
1
91%

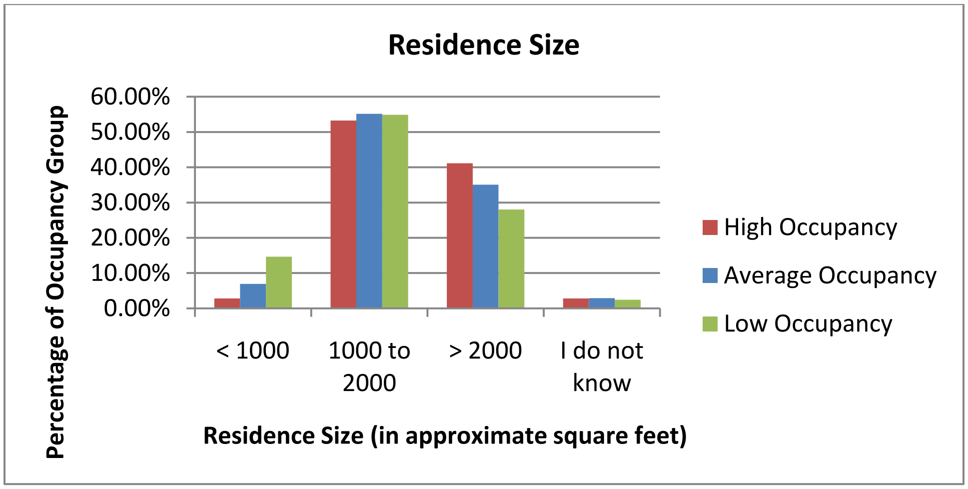

Type of Water Heater
I do not know
1%
Line
21%
Solar
27%
Gas
2%
Electric
49%

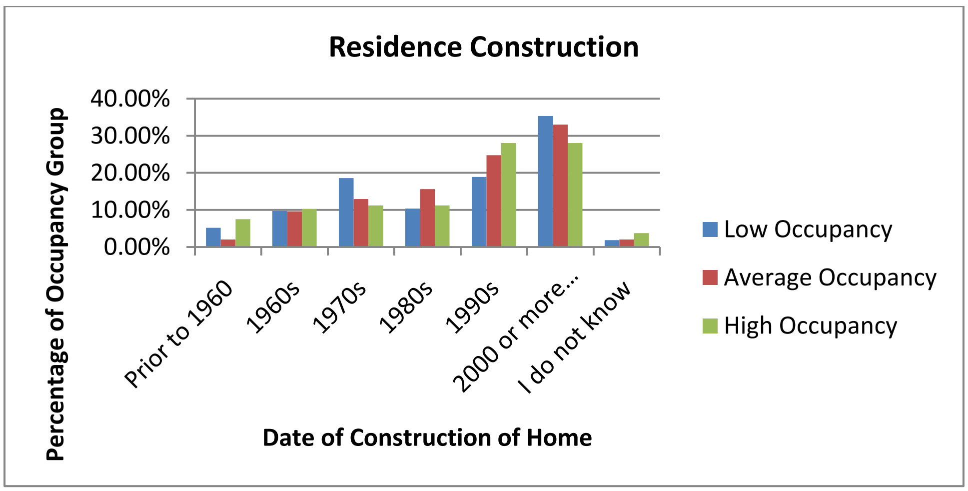

Number of Televisions per Residence
I do not have one 1%
3+ 25%
1 29%
2 45%

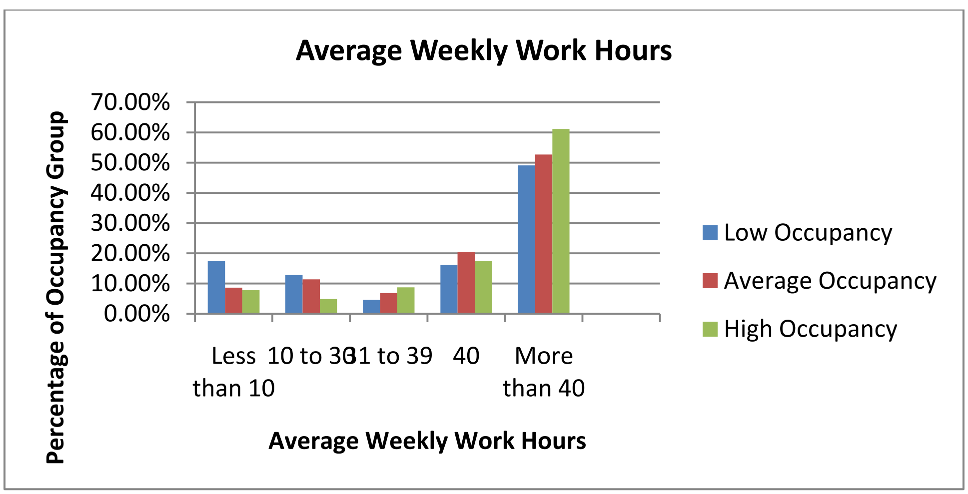

Number of Computers per Residence
3+ 3%
I do not have one 3%
2 38%
1 56%

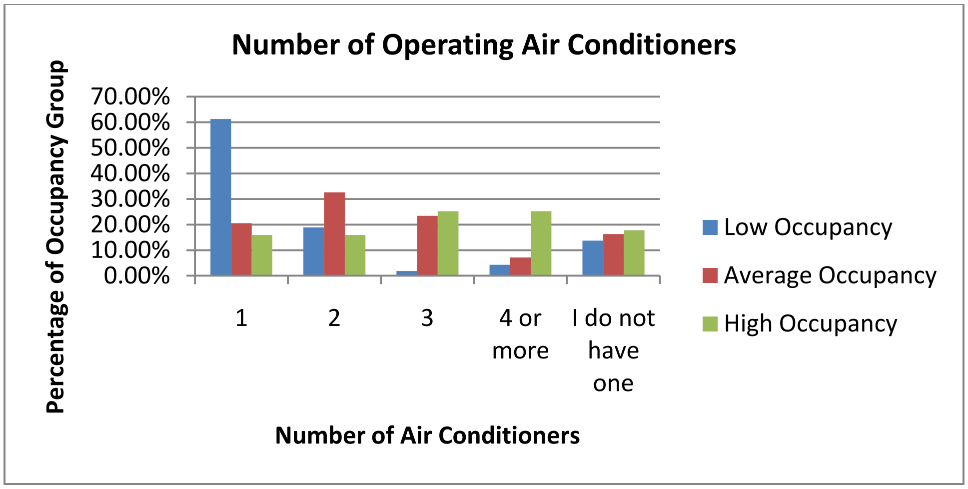

Number of Refrigerators per Residence
3+ 4%
I do not have one 0%
2 18%
1 78%

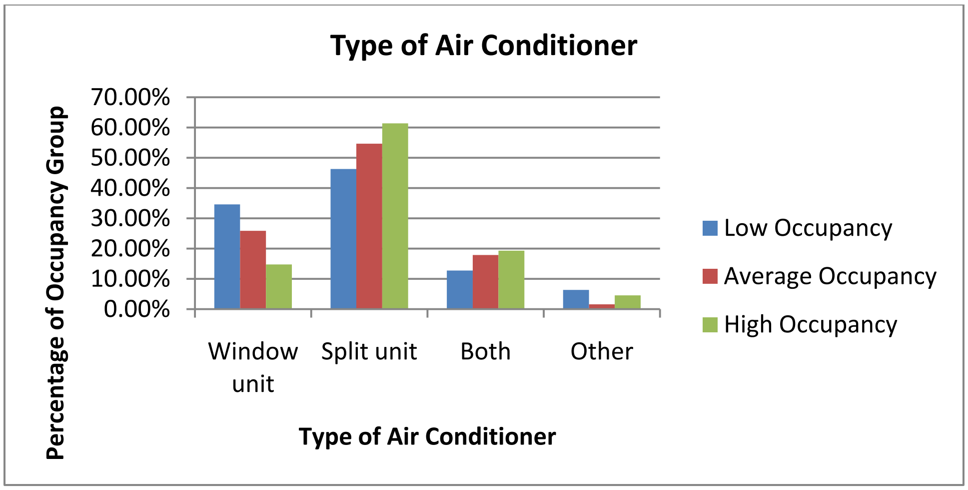
F.6 Comparison Charts for Low, Average, and High Occupancies

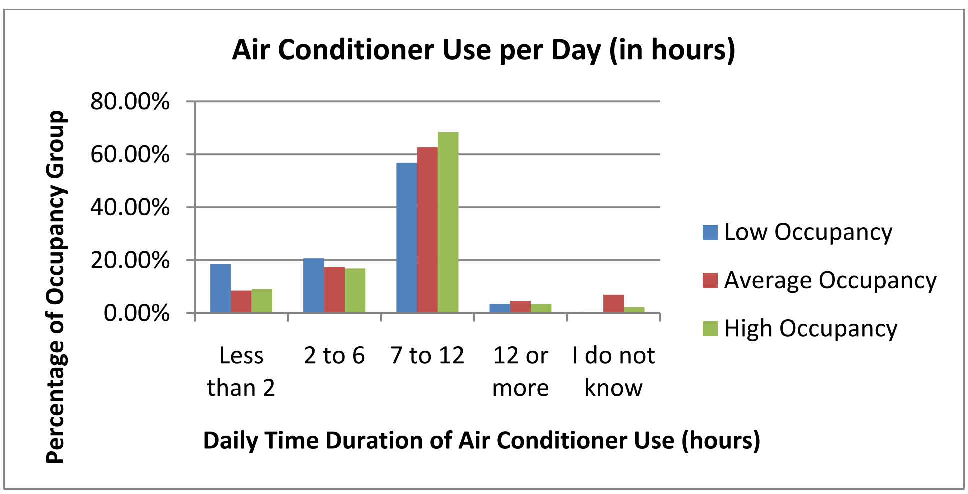


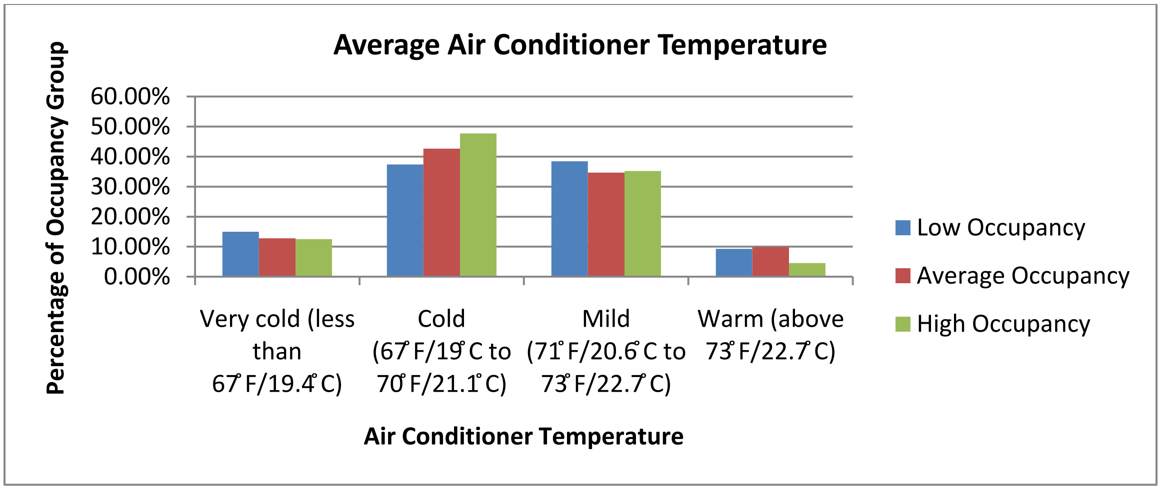


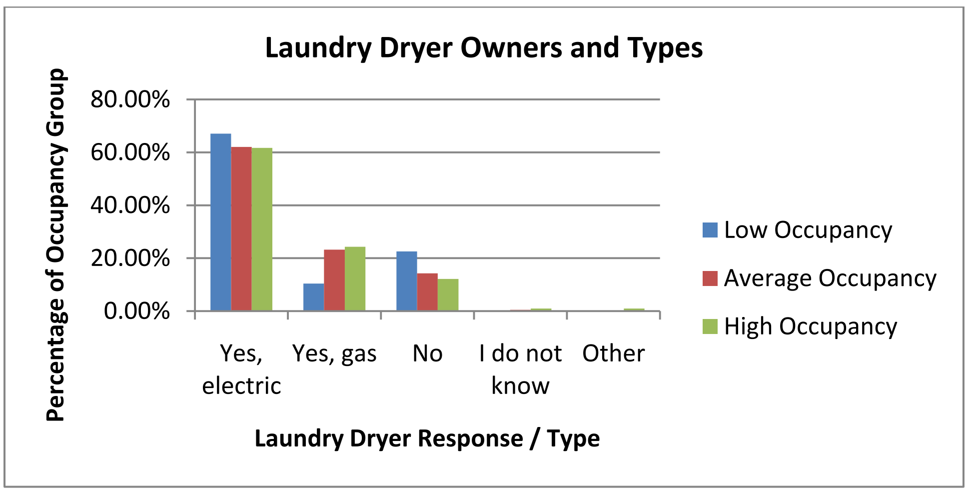


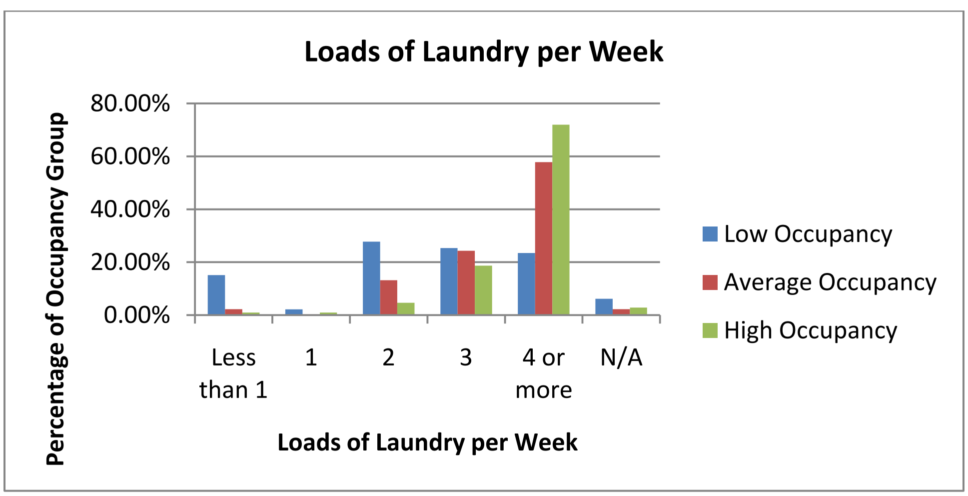

Number of Operating Air Conditioners
Percentage of Occupancy Group
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
1
2
3
4 or more
I do not have one
Number of Air Conditioners
Low Occupancy
Average Occupancy
High Occupancy

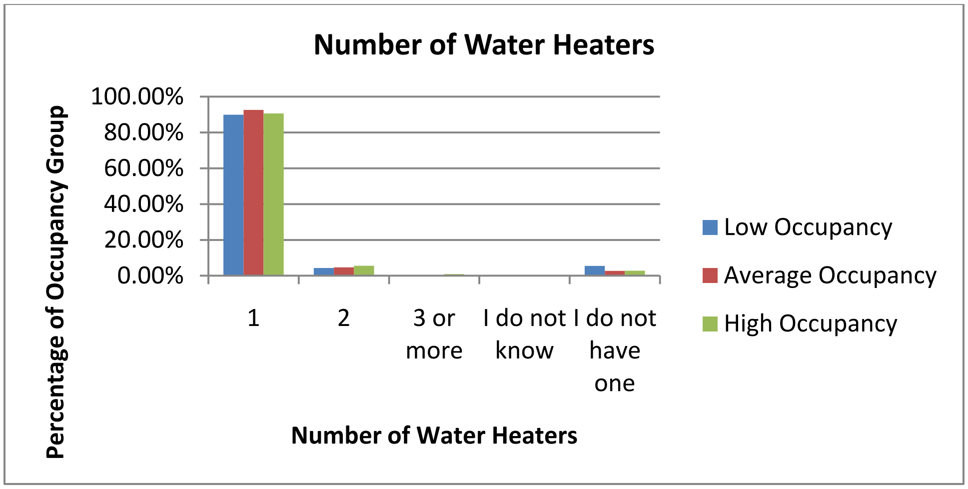

Type of Air Conditioner
Percentage of Occupancy Group
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
Window unit
Split unit
Both
Other
Type of Air Conditioner
Low Occupancy
Average Occupancy
High Occupancy


Air Conditioner Use per Day (in hours)
Percentage of Occupancy Group
80.00%
60.00%
40.00%
20.00%
0.00%
Less than 2
2 to 6
7 to 12
12 or more
I do not know
Daily Time Duration of Air Conditioner Use (hours)
Low Occupancy
Average Occupancy
High Occupancy

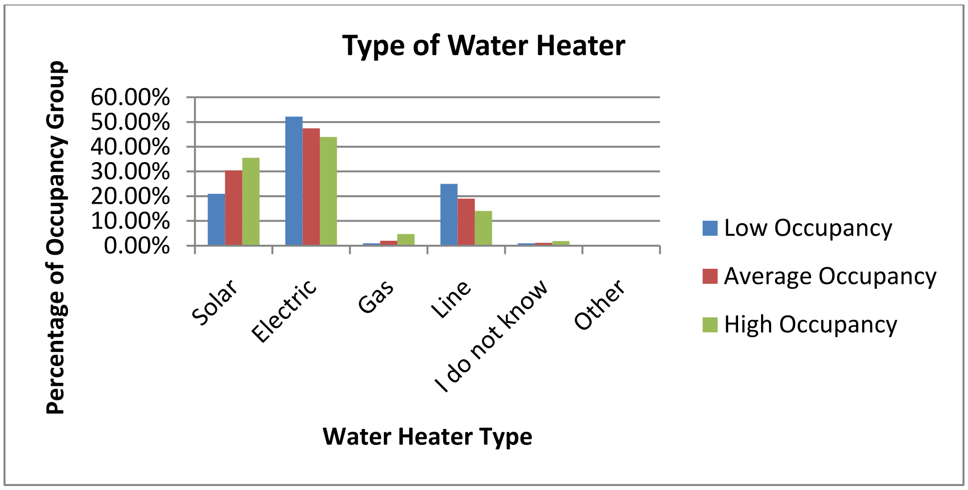

Average Air Conditioner Temperature
Percentage of Occupancy Group
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
Very cold (less than 67˚F/19.4˚C)
Cold (67˚F/19˚C to 70˚F/21.1˚C)
Mild (71˚F/20.6˚C to 73˚F/22.7˚C)
Warm (above 73˚F/22.7˚C)
Air Conditioner Temperature
Low Occupancy
Average Occupancy
High Occupancy


Laundry Dryer Owners and Types
Percentage of Occupancy Group
80.00%
60.00%
40.00%
20.00%
0.00%
Yes, electric
Yes, gas
No
I do not know
Other
Laundry Dryer Response / Type
Low Occupancy
Average Occupancy
High Occupancy

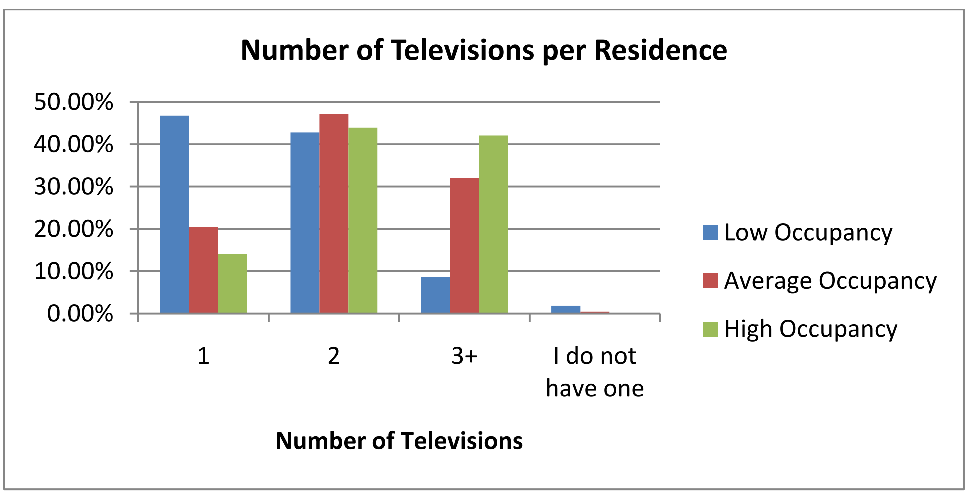

Loads of Laundry per Week
Percentage of Occupancy Group
80.00%
60.00%
40.00%
20.00%
0.00%
Less than 1
1
2
3
4 or more
N/A
Loads of Laundry per Week
Low Occupancy
Average Occupancy
High Occupancy



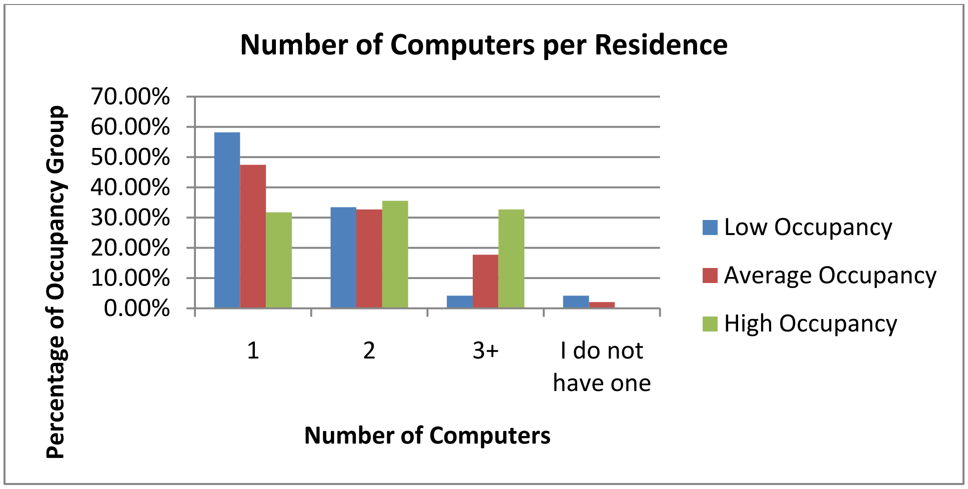
Number of Water Heaters
Percentage of Occupancy Group
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
1
2
3 or more
I do not know
I do not have one
Number of Water Heaters
Low Occupancy
Average Occupancy
High Occupancy

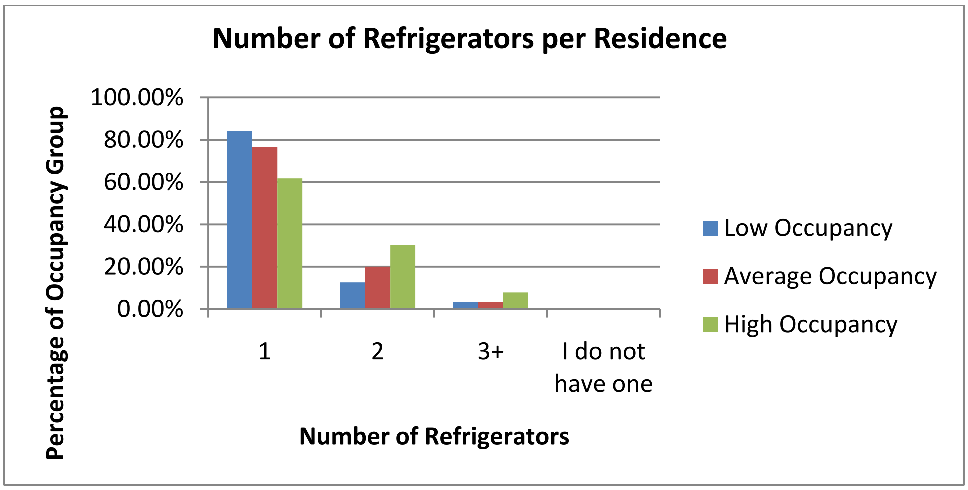


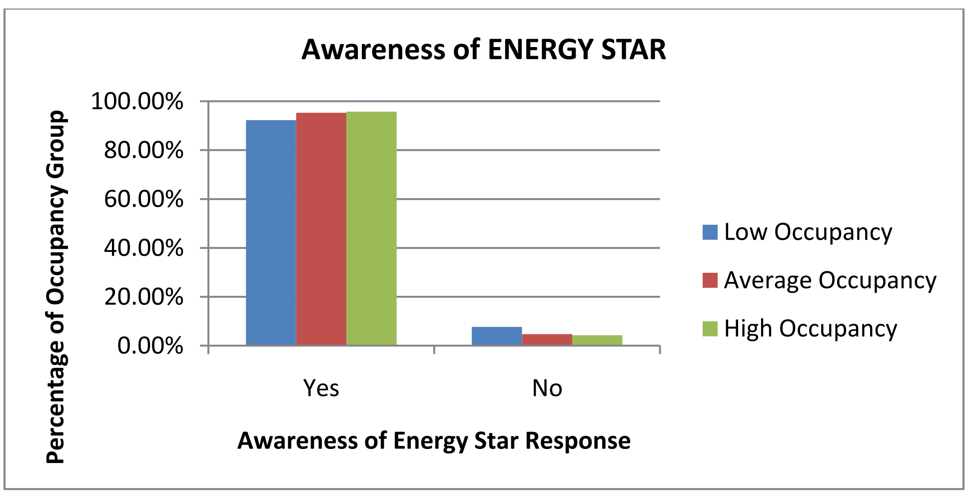
Type of Water Heater
Percentage of Occupancy Group
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
Solar
Electric
Gas
Line
I do not know
Other
Water Heater Type
Low Occupancy
Average Occupancy
High Occupancy

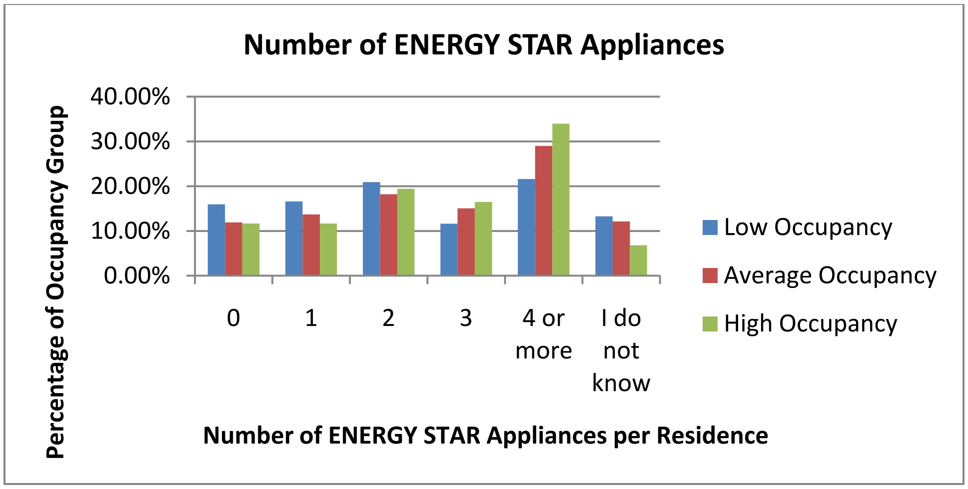


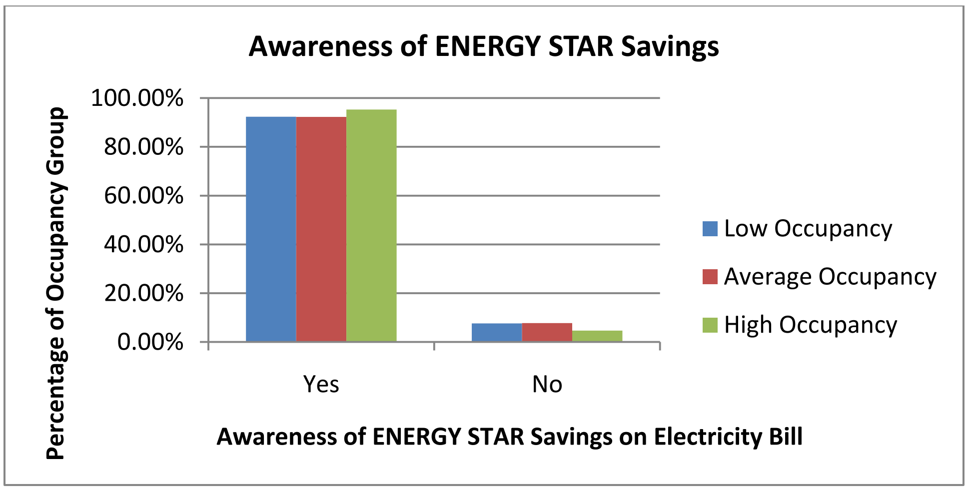
Number of Televisions per Residence
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
1
2
3+
I do not have one
Number of Televisions
Low Occupancy
Average Occupancy
High Occupancy

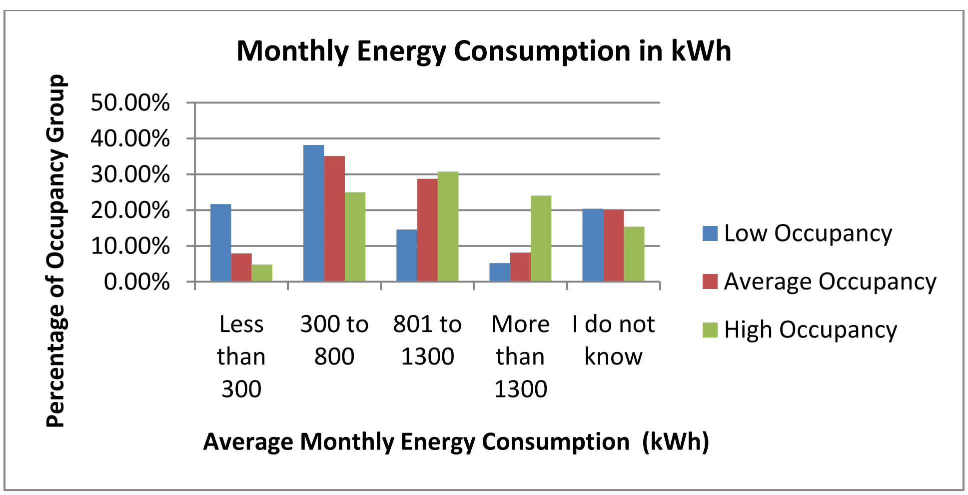

Number of Computers per Residence
Percentage of Occupancy Group
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
1
2
3+
I do not have one
Number of Computers
Low Occupancy
Average Occupancy
High Occupancy

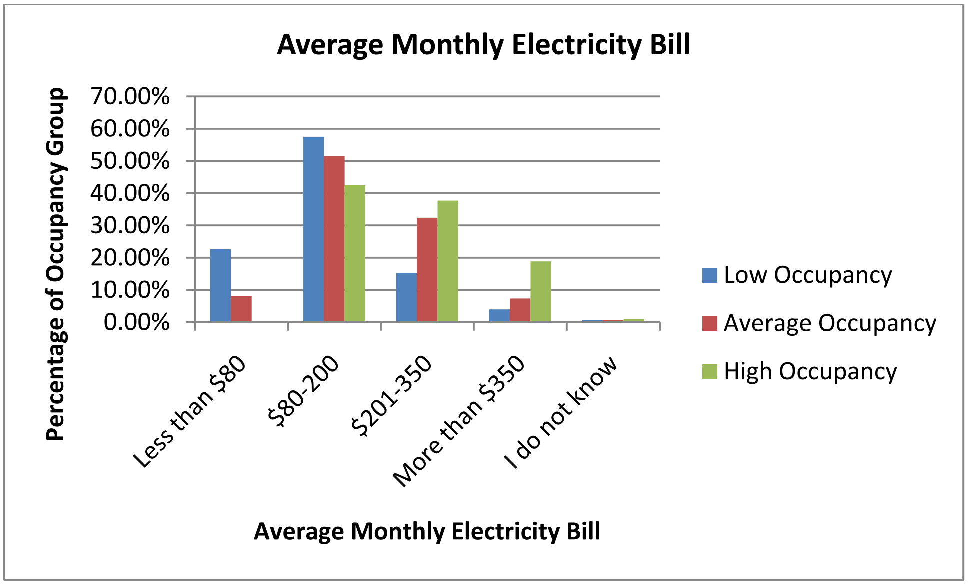

Number of Refrigerators per Residence
Percentage of Occupancy Group
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
1
2
3+
I do not have one
Number of Refrigerators
Low Occupancy
Average Occupancy
High Occupancy


Awareness of ENERGY STAR
Percentage of Occupancy Group
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
Yes
No
Awareness of Energy Star Response
Low Occupancy
Average Occupancy
High Occupancy


Number of ENERGY STAR Appliances
Percentage of Occupancy Group
40.00%
30.00%
20.00%
10.00%
0.00%
0
1
2
3
4 or more
I do not know
Number of ENERGY STAR Appliances per Residence
Low Occupancy
Average Occupancy
High Occupancy


Awareness of ENERGY STAR Savings
Percentage of Occupancy Group
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
Yes
No
Awareness of ENERGY STAR Savings on Electricity Bill
Low Occupancy
Average Occupancy
High Occupancy


Monthly Energy Consumption in kWh
Percentage of Occupancy Group
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
Less than 300
300 to 800
801 to 1300
More than 1300
I do not know
Average Monthly Energy Consumption (kWh)
Low Occupancy
Average Occupancy
High Occupancy


Average Monthly Electricity Bill
Percentage of Occupancy Group
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
Less than $80
$80-200
$201-350
More than $350
I do not know
Low Occupancy
Average Occupancy
High Occupancy
Average Monthly Electricity Bill

Appendix G: Walk-Through Audit Results

G.1 Audit Results #1

Puerto Rico Residential Energy Audit

Names of persons performing audit: ___Colleen and Taylor______________________________

Date: 4/18/10 Time: _9:30__ Outside Temp: ______________________________

Building Information

Address: Guaynabo

Owner: Private Landlord

If landlord, please include name of contact

____

Residence size (in square feet): 1,000

Date of construction: 1978

Last building update occurred:

>5 years 5-10 years 10+ years

Please provide specific renovation dates if known:

____

What types of restorations/renovations have been done on building? New windows, roof resealed (2 months, reflective)

Type of residence: House

How many floors if a house: 1

Average ceiling height: 8

# of Bathrooms 1

# of Bedrooms 3

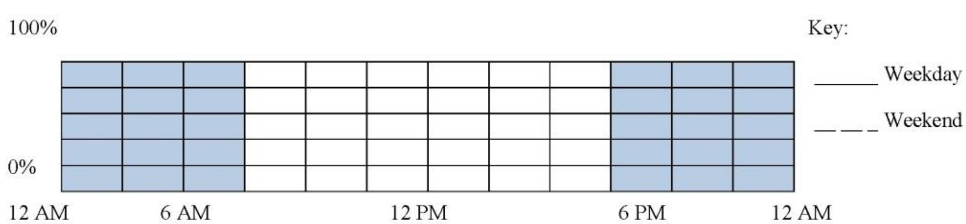
Are there low-flow showerheads? Yes No

Does the house have any other issues? Yes No

Household information

Household size: 3

Daily Occupancy Profile:



Resident Interview

1. High Bills Yes No ______________________
2. Window Problems Yes No Aluminum windows, won't seal correctly
3. Door Problems Yes No ______________________
4. Moisture Issues Yes No ______________________

Do you implement any of the following energy conservation techniques?

1. Turn off and unplug appliances when not in use Yes No ______________________
2. Cool your house with natural ventilation Yes No During Day
3. Use curtains or canvas to keep the sun out of rooms Yes No ______________________
4. Turn off your water heater when not in use Yes No No Water Heater
5. Use lightning fixtures only when necessary Yes No ______________________
6. Purchase ENERGYSTAR appliances Yes No ______________________
7. Use pots with lids while cooking Yes No ______________________
8. Use a pressure cooker or microwave Yes No Sometimes, prefer to
9. Use glass instead of metal while baking Yes No ______________________
10. Limit use of dryers by drying clothing outside Yes No ______________________

Energy Consumption History

Month	KWh	Cost
January	700	$156.75
February	750	$167.72
March	690	$161.63
April	660	$121.31
May	600	$117.63
June	700	$139.31
July	660	$135.91
August	720	$138.87
September	800	$162.43
October	750	$151.90
November	720	$153.24
December	770	$163.52
Total Year	8,520	$1,770.22

Cooling

Conditioned area of home (sq. ft.) ________________________

# of Thermostats ________

Are thermostats programmable? Yes No

Is there air conditioning? Yes No

# of Window Units _______

# of Split Units ____4_____

Frequency of cleaning: ____2-3 Months___

Filter clean: Yes No

Condensate line issues: ________________

Dehumidifier: Yes No

Unit #				
Brand				
Type				
Output BTU				
Age	New	New	New	New
Condition	Gd Fair Pr	Gd Fair Pr	Gd Fair Pr	Gd Fair Pr
Frequency of use				
Setting	61			
Location	Bed	Bed	Bed	Exercise
ENERGYSTAR	Yes No	Yes No	Yes No	Yes No

Number of fans: ______3___________

Notes (types, location) 1 ceiling & 1 stand-up (both in living room), 1 ceiling in exercising room

Water Heater

Unit #		
Size	Line	
Fuel	Electric	
Age	New	
Condition	New	
Output BTU		
Location	Closet	
Temp. Setting		

Is the water heater wrapped? Yes No

Lighting

Number of fixtures: ____10_____

Number of fluorescent lightbulbs: __9__

Comments: (Ex: Timers, switches, motion sensors) ____ ______________________________

Other Appliances

	ENERGYSTAR	Size	Age	Condition	Frequency of Use	Notes
Refrigerator 1	Yes No	Standard		Good Fair Poor	Daily	
Refrigerator 2	Yes No			Good Fair Poor		
Freezer	Yes No			Good Fair Poor		
Dishwasher	Yes No			Good Fair Poor		
Washing Machine (491 kWhr/yr)	Yes No		6	Good Fair Poor		
Dehumidifier	Yes No			Good Fair Poor		
Dryer	Yes No		6	Good Fair Poor		
Cooking Range/Oven	Yes No	Standard		Good Fair Poor		
Television (2 tvs)	Yes No		5-8 yrs	Good Fair Poor		
Computer	Yes No	Standard		Good Fair Poor		

Dryer Fuel: Gas Electric

G.2 Audit Results #2

Puerto Rico Residential Energy Audit

Names of persons performing audit: Colleen Heath, Aaron Champagne, Taylor North, Brent Evansen, Andre Mesa

Date: April 5, 2010 Time: 8:45 AM Outside Temp: ______

Building Information

Address: Calle 6 I 12 Urb. Parado Alto Guaynabo

Owner: ==Private== Landlord

If landlord, please include name of contact ______

Residence size (in square feet): Approx. 1,800

Date of construction: 1985

Last building update occurred:

>5 years 5-10 years ==10+ years==

Please provide specific renovation dates if known: house never renovated

What types of restorations/renovations have been done on building? ______

Type of residence: house

How many floors if a house: 2

Average ceiling height: ______

# of Bathrooms 2.5

# of Bedrooms 4

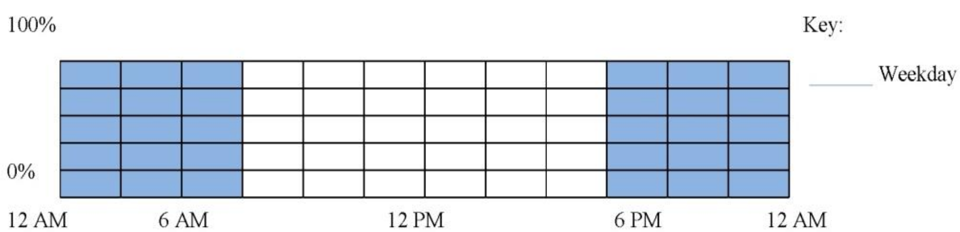
Are there low-flow showerheads? Yes No

Does the house have any other issues? Yes ==No==

Household information

Household size: 4

Daily Occupancy Profile:



Resident Interview

1. High Bills Yes No ____________________
2. Window Problems Yes No ____________________
3. Door Problems Yes No ____________________
4. Moisture Issues Yes No ____________________

Do you implement any of the following energy conservation techniques?

1. Turn off and unplug appliances when not in use Yes No ____________________
2. Cool your house with natural ventilation Yes No ____________________
3. Use curtains or canvas to keep the sun out of rooms Yes No ____________________
4. Turn off your water heater when not in use Yes No ____________________
5. Use lightning fixtures only when necessary Yes No ____________________
6. Purchase ENERGYSTAR appliances Yes No ____________________
7. Use pots with lids while cooking Yes No ____________________
8. Use a pressure cooker or microwave Yes No ____________________
9. Use glass instead of metal while baking Yes No ____________________
10. Limit use of dryers by drying clothing outside Yes No ____________________

Energy Consumption History

Month	KWh	Cost
January	2740	580.92
February	2080	465.02
March		
April		
May		
June		
July		
August		
September		
October		
November		
December		
Total Year		

Cooling

Conditioned area of home (sq. ft.) _4 bedrooms airconditioned_

# of Thermostats __1______

Are thermostats programmable? Yes No

Is there air conditioning? Yes No

# of Window Units _4______

# of Split Units __0________

Frequency of cleaning: _twice a month_________

Filter clean: Yes No

Condensate line issues: ________________

Dehumidifier: Yes No

Unit #	1	2	3	4
Brand	Frigidair	Frigidair	Frigidair	
Type	Window	Window	Window	Window
Output BTU	12,000	12,000	12,000	16,000
Age				
Condition	Gd Fair Pr	Gd Fair Pr	Gd Fair Pr	Gd Fair Pr
Frequency of use	Nightly	Nightly	Nifhtly	Nightly
Setting	69			
Location	Bedroom	Bedroom	Bedroom	Master Bedroom
ENERGYSTAR	Yes No	Yes No	Yes No	Yes No

Number of fans: _4 ceiling, 1 standing___________

Notes (types, location) _______________________

Water Heater

Unit #	1	
Size	30 gal	
Fuel	Electric	
Age		
Condition	Fair	
Output BTU	4714 kwH/yr	
Location	Bathroom	
Temp. Setting		

Is the water heater wrapped? Yes No

Lighting

Number of fixtures: __20____________

Number of fluorescent lightbulbs: _12___

Comments: (Ex: Timers, switches, motion sensors)

____

____

Other Appliances

	ENERGYSTAR	Size	Age	Condition	Frequency of Use	Notes
Refrigerator 1	Yes No	Large		Good Fair Poor	Daily	
Refrigerator 2	Yes No			Good Fair Poor		
Freezer	Yes No	Large		Good Fair Poor	Daily	
Dishwasher	Yes No			Good Fair Poor		
Washing Machine	Yes No	Standard		Good Fair Poor	Daily	
Dehumidifier	Yes No			Good Fair Poor		
Dryer	Yes No	Standard		Good Fair Poor	Daily	
Cooking Range/Oven	Yes No	Standard		Good Fair Poor		
Television	Yes No			Good Fair Poor		4 televisions
Computer	Yes No			Good Fair Poor		2 laptops

Dryer Fuel: Gas Electric

G.3 Audit Results #3

Puerto Rico Residential Energy Audit

Names of persons performing audit: _Colleen Heath, Aaron Champagne, Taylor North, Brent Evansen_

Date: _4/5/2010__ Time: _8:15 AM_____ Outside Temp: _76°__________________________

Building Information

Address: _Guaynbabo________________

Owner: Private (highlighted) Landlord

If landlord, please include name of contact

____

Residence size (in square feet): _Approx. 2,000_

Date of construction: _1990____

Last building update occurred:

>5 years 5-10 years (highlighted) 10+ years

Please provide specific renovation dates if known:

____

What types of restorations/renovations have been done on building? _new doors and windows______

Type of residence: ____________________

How many floors if a house: _House____

Average ceiling height: __8 ft__________

# of Bathrooms _2.5_____

# of Bedrooms __4___

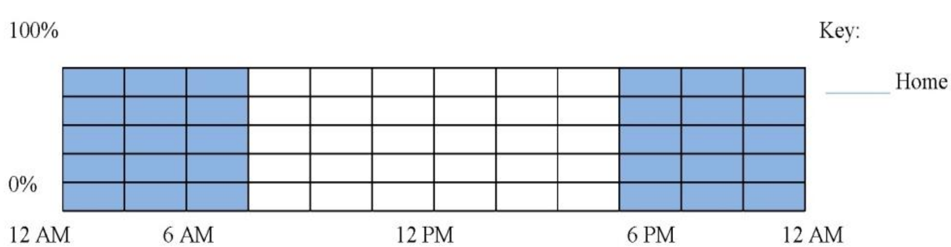
Are there low-flow showerheads? Yes No (highlighted)

Does the house have any other issues? Yes No (highlighted)

Household information

Household size: _2_____

Daily Occupancy Profile:



Resident Interview

1. High Bills Yes No ______________________
2. Window Problems Yes No ______________________
3. Door Problems Yes No ______________________
4. Moisture Issues Yes No unsure______________________

Do you implement any of the following energy conservation techniques?

1. Turn off and unplug appliances when not in use Yes No ______________
2. Cool your house with natural ventilation Yes No ______________
3. Use curtains or canvas to keep the sun out of rooms Yes No ______________
4. Turn off your water heater when not in use Yes No ______________
5. Use lightning fixtures only when necessary Yes No ______________
6. Purchase ENERGYSTAR appliances Yes No ______________
7. Use pots with lids while cooking Yes No ______________
8. Use a pressure cooker or microwave Yes No ______________
9. Use glass instead of metal while baking Yes No ______________
10. Limit use of dryers by drying clothing outside Yes No ______________

Energy Consumption History

Month	KWh	Cost
January	450	$100.90
February	1110	$248.05
March	1180	$276.14
April		
May		
June		
July		
August		
September		
October		
November	180	$38.60
December	450	$95.71
Total Year		

Cooling

Conditioned area of home (sq. ft.)
_All_____________

# of Thermostats _4____

Are thermostats programmable? Yes No

Is there air conditioning? Yes No

# of Window Units _1____

# of Split Units _3______

Frequency of cleaning: _Monthly______

Filter clean: Yes No

Condensate line issues: ________________

Dehumidifier: Yes No

Unit #	1	2	3	4
Brand	Panasonic	Panasonic	Panasonic	Panasonic
Type	Window	Split	Split	Split
Output BTU				
Age	New	New	New	New
Condition	Gd Fair Pr	Gd Fair Pr	Gd Fair Pr	Gd Fair Pr
Frequency of use	Nightly	Nightly	Nightly	Never
Setting				
Location				
ENERGYSTAR	Yes No	Yes No	Yes No	Yes No

Number of fans: __2___________________

Notes (types, location) _living room, bedroom___

Water Heater

Unit #	1	
Size	14 gallons	
Fuel		
Age		
Condition	Good	
Output BTU		
Location	Bathroom	
Temp. Setting		

Is the water heater wrapped? Yes No

Lighting

Number of fixtures: _23_____________

Number of fluorescent lightbulbs: _5_____

Comments: (Ex: Timers, switches, motion sensors)
_Dimmers used, 12 halogen bulbs_______________

Other Appliances

	ENERGYSTAR	Size	Age	Condition	Frequency of Use	Notes
Refrigerator 1	Yes No	Standard	3 months	Good Fair Poor	Daily	
Refrigerator 2	Yes No			Good Fair Poor		Not applicable
Freezer	Yes No			Good Fair Poor		Part of refrigeration unit
Dishwasher	Yes No			Good Fair Poor		Not in use
Washing Machine	Yes No		8 years	Good Fair Poor		
Dehumidifier	Yes No			Good Fair Poor		Not applicable
Dryer	Yes No		8 years	Good Fair Poor		
Cooking Range/Oven	Yes No			Good Fair Poor		
Television	Yes No		3 months	Good Fair Poor		2 televisions
Computer	Yes No			Good Fair Poor		

Dryer Fuel: Gas Electric

G.4 Audit Results #4

Puerto Rico Residential Energy Audit

Names of persons performing audit: _Colleen Heath, Aaron Champagne, Taylor North, Brent Evansen_

Date: _4/8/2010____ Time: _9:05_____ Outside Temp: _81°____________________________

Building Information

Address: _Carolina____________________

Owner: Private Landlord

If landlord, please include name of contact

____

Residence size (in square feet): _Approx. 2,000_

Date of construction: _2005_________

Last building update occurred:

>5 years 5-10 years 10+ years

Please provide specific renovation dates if known: _Four years ago______________________

What types of restorations/renovations have been done on building? __new windows, new doors___

Type of residence: _Apartment________________

How many floors if a house: __2_________

Average ceiling height: _8 ft________________

# of Bathrooms _3_____

# of Bedrooms _3______

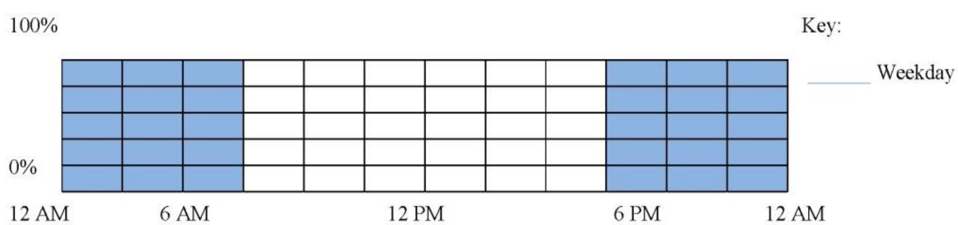
Are there low-flow showerheads? Yes No

Does the house have any other issues? Yes No

Household information

Household size: _4______

Daily Occupancy Profile:



Resident Interview

1. High Bills Yes No
2. Window Problems Yes No some stick, usually windows are open
3. Door Problems Yes No
4. Moisture Issues Yes No

Do you implement any of the following energy conservation techniques?

1. Turn off and unplug appliances when not in use Yes No
2. Cool your house with natural ventilation Yes No sometimes
3. Use curtains or canvas to keep the sun out of rooms Yes No
4. Turn off your water heater when not in use Yes No
5. Use lightning fixtures only when necessary Yes No
6. Purchase ENERGYSTAR appliances Yes No
7. Use pots with lids while cooking Yes No
8. Use a pressure cooker or microwave Yes No
9. Use glass instead of metal while baking Yes No
10. Limit use of dryers by drying clothing outside Yes No apartment regulations

Energy Consumption History

Month	KWh	Cost
January	980	$219.29
February	1100	$245.83
March	1320	$308.87
April	1210	$222.10
May	1150	$221.44
June	1290	$256.42
July	1530	$314.59
August	1250	$240.81
September	1170	$237.38
October	1410	$285.23
November	1070	$227.56
December	1310	$284.29
Total Year	14,790	$3063.81

Cooling

Conditioned area of home (sq. ft.)
_1,000___________________

# of Thermostats _4_______

Are thermostats programmable? Yes No

Is there air conditioning? Yes No

# of Window Units _3 (wall packs

# of Split Units _1______

Frequency of cleaning: _Every two months_

Filter clean: Yes No

Condensate line issues: ________________

Dehumidifier: Yes No

Unit #	1	2	3	4
Brand				
Type	Wall pack	Wall pack	Wall pack	Split
Output BTU	12,000	12,000	15,000	24,000
Age			6 months	
Condition	Gd Fair Pr	Gd Fair Pr	Gd Fair Pr	Gd Fair Pr
Frequency of use	Never	Nightly	Nightly	Nightly
Setting	Off			
Location	Bedroom	Bedroom	Bedroom	Living Room
ENERGYSTAR	Yes No	Yes No	Yes No	Yes No

Number of fans: _3_______

Notes (types, location) _in bedrooms__________

Water Heater

Unit #	1	
Size		
Fuel	Electric	
Age	5 years	
Condition	Good	
Output BTU		
Location	kitchen	
Temp. Setting		

Is the water heater wrapped? Yes No

Lighting

Number of fixtures: _18_______________

Number of fluorescent lightbulbs: _10___

Comments: (Ex: Timers, switches, motion sensors)
_Bedrooms have two flourescent bulbs and 2 dummy incandescent (per fixture)__

Other Appliances

	ENERGYSTAR	Size	Age	Condition	Frequency of Use	Notes
Refrigerator 1	Yes No	Standard	15	Good Fair Poor	Daily	
Refrigerator 2	Yes No			Good Fair Poor		Not Applicable
Freezer	Yes No			Good Fair Poor		With Refierator
Dishwasher	Yes No			Good Fair Poor		Not Applicable
Washing Machine	Yes No	Standard	15	Good Fair Poor		
Dehumidifier	Yes No			Good Fair Poor		Not in use
Dryer	Yes No	Standard	15	Good Fair Poor		
Cooking Range/Oven	Yes No	Standard	10	Good Fair Poor		
Television	Yes No			Good Fair Poor		Two 50", one 12"
Computer	Yes No			Good Fair Poor		Laptop
Microwave	Yes No	Standard	5	Good Fair Poor		13A

Dryer Fuel: Gas Electric

G.5 Audit Results #5

Puerto Rico Residential Energy Audit

Names of persons performing audit: Colleen Heath and Taylor North

Date: 4/14/2010 Time: 8:15 AM Outside Temp: 80°

Building Information

Address: Guaynabo

Owner: Private Landlord

If landlord, please include name of contact

Residence size (in square feet): __________

Date of construction: 1995

Last building update occurred:

>5 years 5-10 years 10+ years

Please provide specific renovation dates if known: currently being remodeled

What types of restorations/renovations have been done on building? new doors, new appliances

Type of residence: Apartment

How many floors if a house: 1

Average ceiling height: 8 ft

# of Bathrooms 2

# of Bedrooms 3

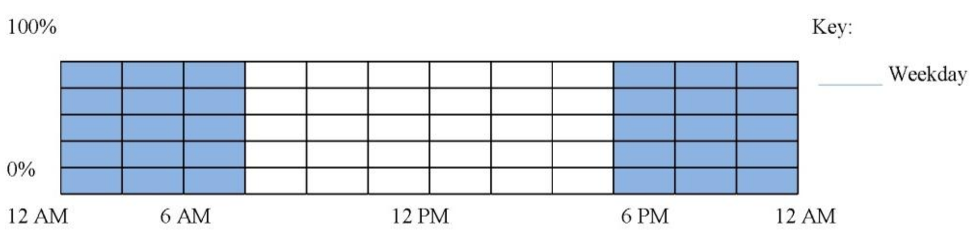
Are there low-flow showerheads? Yes No

Does the house have any other issues? Yes No

Household information

Household size: 2

Daily Occupancy Profile:



Resident Interview

1. High Bills Yes No ____________________
2. Window Problems Yes No ____________________
3. Door Problems Yes No ____________________
4. Moisture Issues Yes No ____________________

Do you implement any of the following energy conservation techniques?

1. Turn off and unplug appliances when not in use Yes No _usually____________
2. Cool your house with natural ventilation Yes No ____________________
3. Use curtains or canvas to keep the sun out of rooms Yes No ____________________
4. Turn off your water heater when not in use Yes No _usually___
5. Use lightning fixtures only when necessary Yes No ____________________
6. Purchase ENERGYSTAR appliances Yes No ____________________
7. Use pots with lids while cooking Yes No ____________________
8. Use a pressure cooker or microwave Yes No ____________________
9. Use glass instead of metal while baking Yes No __sometimes__________
10. Limit use of dryers by drying clothing outside Yes No ____________________

Energy Consumption History

Month	KWh	Cost
January	310	70.34
February	210	48.57
March	330	78.09
April		
May		
June		
July		
August		
September		
October		
November	40	10.64
December		
Total Year		

Cooling

Conditioned area of home (sq. ft.) ________________________

# of Thermostats ________

Are thermostats programmable? Yes No

Is there air conditioning? Yes No

# of Window Units _2 wall packs____

# of Split Units _1 inverter____

Frequency of cleaning: _every 3 weeks__

Filter clean: Yes No

Condensate line issues: ________________

Dehumidifier: Yes No

Unit #	1	2	3	
Brand				
Type	Wall pack	Wall pack	inverter	
Output BTU				
Age	New	New	new	
Condition	Gd Fair Pr	Gd Fair Pr	Gd Fair Pr	Gd Fair Pr
Frequency of use	Nightly			
Setting				
Location	Bedroom	Bedroom		
ENERGYSTAR	Yes No	Yes No	Yes No	Yes No

Number of fans: _3_____

Notes (types, location) _ceiling fans, living room and bedrooms_____________

Water Heater

Unit #		
Size		
Fuel	Electric	
Age	New	
Condition	Good	
Output BTU		
Location	Closet	
Temp. Setting		

Is the water heater wrapped? Yes No

Lighting

Number of fixtures: _10___________

Number of fluorescent lightbulbs: _10_____

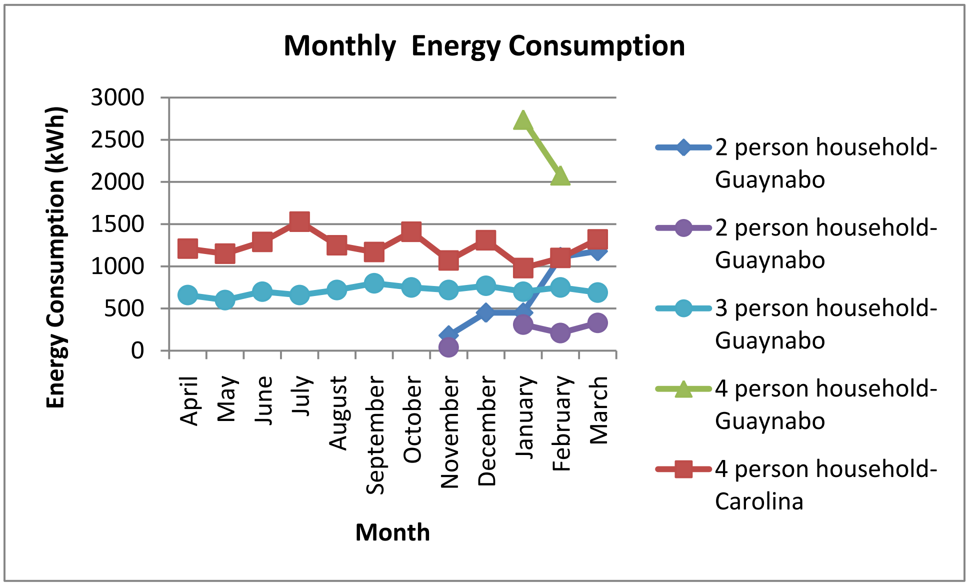
Comments: (Ex: Timers, switches, motion sensors) ____

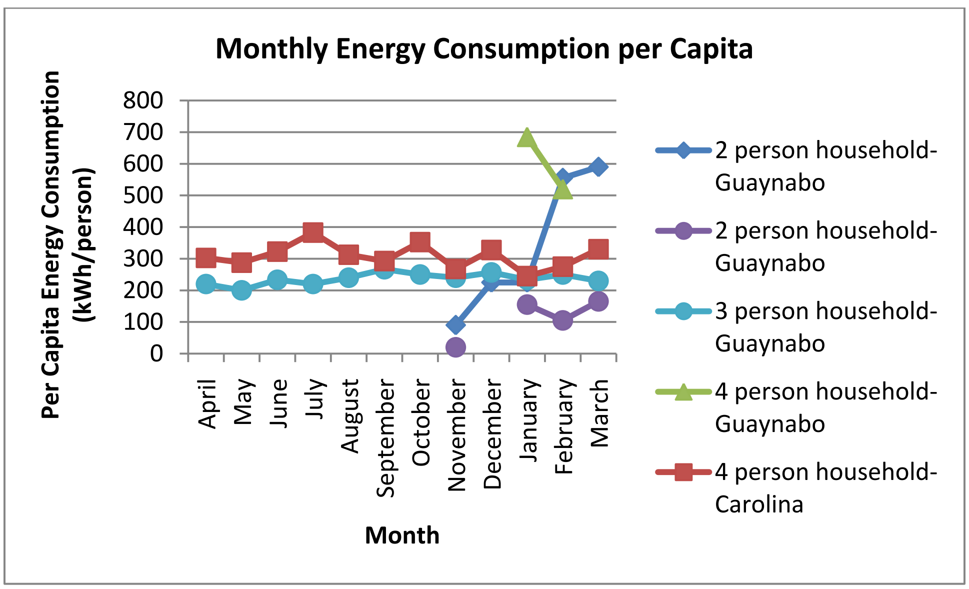
Other Appliances

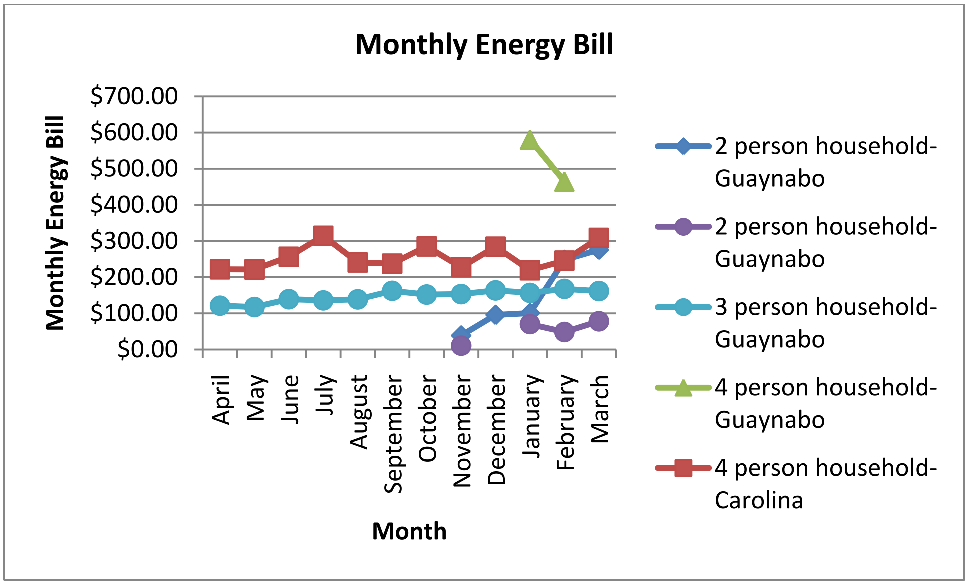
	ENERGYSTAR	Size	Age	Condition	Frequency of Use	Notes
Refrigerator 1	Yes No	Large	new	Good Fair Poor	Daily	
Refrigerator 2	Yes No			Good Fair Poor		Not Applicable
Freezer	Yes No			Good Fair Poor		Part of refrigeration unit
Dishwasher	Yes No			Good Fair Poor		None
Washing Machine	Yes No		new	Good Fair Poor		
Dehumidifier	Yes No			Good Fair Poor		Not Applicable
Dryer	Yes No		new	Good Fair Poor		
Cooking Range/Oven	Yes No		new	Good Fair Poor		Gas stove
Television	Yes No	Small	new	Good Fair Poor		
Computer	Yes No			Good Fair Poor		
Microwave	Yes No		New	Good Fair Poor		

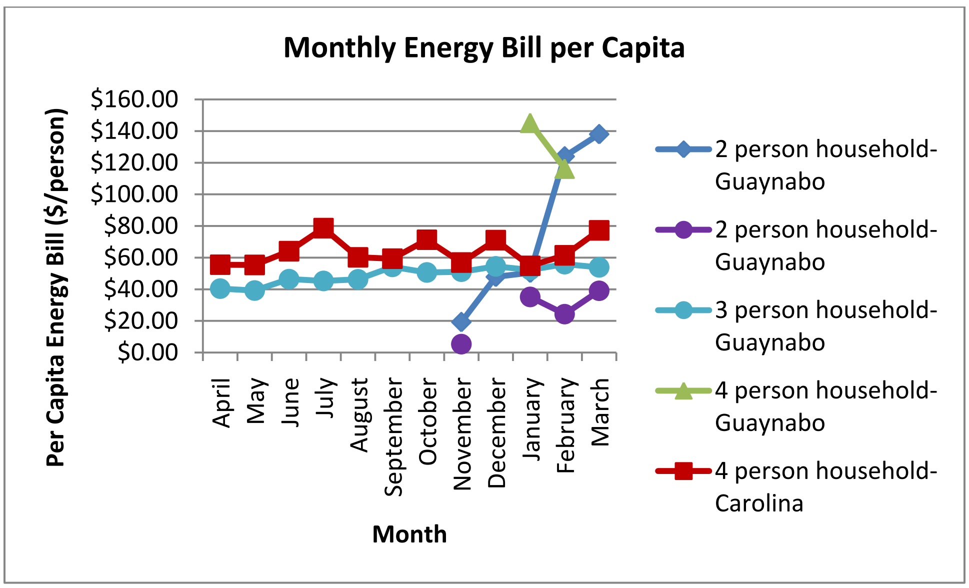
Dryer Fuel: Gas Electric

G.6 Comparative Consumption and Cost Graphs






Monthly Energy Bill
Monthly Energy Bill
$700.00
$600.00
$500.00
$400.00
$300.00
$200.00
$100.00
$0.00
April
May
June
July
August
September
October
November
December
January
February
March
Month
2 person household-Guaynabo
2 person household-Guaynabo
3 person household-Guaynabo
4 person household-Guaynabo
4 person household-Carolina


Monthly Energy Bill per Capita
Per Capita Energy Bill ($/person)
$160.00
$140.00
$120.00
$100.00
$80.00
$60.00
$40.00
$20.00
$0.00
April
May
June
July
August
September
October
November
December
January
February
March
Month
2 person household-Guaynabo
2 person household-Guaynabo
3 person household-Guaynabo
4 person household-Guaynabo
4 person household-Carolina