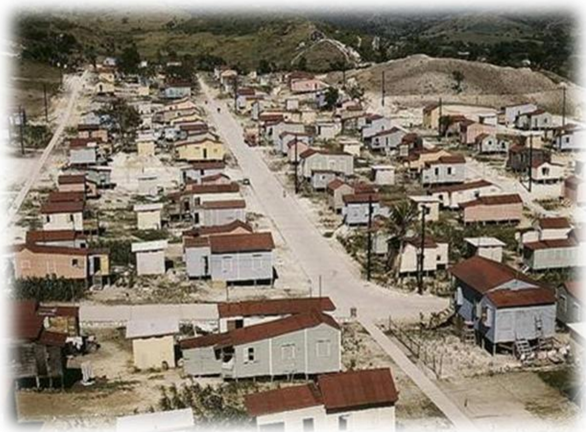
Puerto Rico Residential Energy

Sponsored by the Puerto Rico Energy Affairs Administration (PREAA)



Project Proposal submitted to the
Puerto Rico Energy Affairs Administration

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Chapter 1: Introduction

The growing dependency on fossil fuels has had detrimental effects on the global economy and the efficiency of energy use. High energy costs and the collapse of the economy demand an increased awareness for energy conservation. On the island of Puerto Rico, the need for efficient energy is magnified due to the reliance on foreign oil for the production of power. The island is experiencing significant issues with energy consumption and efficiency and is in need of a method to conserve energy.

This project is sponsored by the Puerto Rico Energy Affairs Administration (PREAA), which works in conjunction with many government sectors, such as the Environmental Protection Agency (EPA), to address energy consumption. The PREAA is responsible for administering energy policy and developing conservation strategies on the island. Some of the major services of the Puerto Rico Energy Affairs Administration include: energy inspections of lighting systems for governmental, industrial, and commercial facilities, technical advice to businesses for conservation and efficient energy use, distribution of energy related information through regular publications, educational programs regarding energy efficient practices, and the promotion of alternative energy projects (www.aae.gobierno.pr, 2010). The PREAA is an important organization that takes on many roles in supporting energy efficiency in Puerto Rico.

The Puerto Rico Energy Affairs Administration is located in the thriving city of San Juan, Puerto Rico. San Juan is the largest manufacturing and processing center on the island. Petroleum and sugar refineries along with cement, metal, and pharmaceutical production sites are prevalent within this area. The metropolitan area of San Juan is comprised of three regions: Old San Juan; the beach and resort areas, known as the Condado; and outlying communities, including Rio Píedras, Hato Rey and Santurce (www.topuertorico.org, 2010). Within these regions, 1.22 million people inhabit San Juan, representing 31% of Puerto Rico's entire population (www.ifhp.org, 2008). With such a large population density, reductions in energy use on the individual level could yield substantial benefits toward lowering residential energy consumption for the entire city.

The PREAA wants to understand current residential energy use for low-income residences in metropolitan San Juan. This study will culminate in the development of energy efficiency guidelines similar to the International Energy Conservation Code (IECC) for the entire island. Our project will prove vital to both the Puerto Rico Energy Affairs Administration and the island of Puerto Rico. The findings could directly impact the welfare of Puerto Rico's citizens because the recent soaring energy costs are causing economic hardships for low-income residents. Another compounding issue for this project is the electricity generation and distribution monopoly held by the Puerto Rico Electric Power Authority (PREPA), which owns a significant majority of the energy generation plants on the island (L.M. Jimenez, personal communication, Dec. 14, 2009). The underlying issue that will be addressed in this study is the lack of any existing energy efficiency rating system for the island of Puerto Rico.

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 will investigate alternative energies and conservation strategies that could decrease the expenses associated with residential energy in low-income homes. The recent advancements in alternative residential energy forms and practices, such as solar power, wind power, and fluorescent light bulbs, for example, can significantly improve energy efficiency. Our project will seek to recommend some of these viable innovative techniques for use in low-income residences. Energy conservation and efficiency projects are effective means of ensuring that future populations are not negatively impacted by our current generation's economic recession and our overconsumption of natural resources.

The goal of this project is to develop energy efficiency recommendations that will aid in the development of a residential energy conservation code and home energy efficiency rating system. Objectives that will be met to achieve this goal include: determining current energy use in low-income Puerto Rican homes through research and interviews; formulating a set of techniques for an energy-efficient low-income housing model; and developing a list of the most effective recommendations for energy efficiency. The outcomes of this project should be useful for the Puerto Rico Energy Affairs Administration in developing an energy conservation code to enable low-income residences to implement energy efficient features and practices.

In the following chapters, we will evaluate pertinent literature and develop the methodology that will be followed to achieve our goal. We will characterize the low-income residences of Puerto Rico, develop a general understanding of alternative residential energy forms, identify similar energy efficiency rating systems and case studies that may be applicable to this project, and explore the contextual issues that arise from our problem. An understanding of these components is essential toward developing an effective methodology to analyze energy use in Puerto Rico and accomplishing our outlined goal for the Puerto Rico Energy Affairs Administration.

Chapter 2: Background & Literature Review

The island of Puerto Rico currently lacks any existing energy conservation code and 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 has requested that our group analyze low-income residential energy use and develop a set of guidelines to aid in the development of a residential energy conservation code. The scope of work for the project includes determining a baseline for low-income residential energy conservation use and proposing practical solutions to enhance the energy efficiency of housing units.

In order to effectively meet these objectives, it is important to develop a thorough understanding of the topics that will be explored in our study. The review of the relevant literature presented in this chapter aided our general understanding of the characteristics of low-income housing in Puerto Rico, energy use and consumption patterns, the benefit of energy simulations, existing energy conservation guidelines (i.e. energy codes, rating systems, and case studies), and the feasibility of alternative energy and energy saving practices. The information pertaining to these topics is critical toward assessing energy use in Puerto Rico and developing practical guidelines to improve energy efficiency.

2.1 Low-Income Residences and Families in Puerto Rico

When defining "low-income," one must first look at the average annual income of the residents in the region. For the purpose of this study, we will be reviewing the average annual salary of low-income citizens in the metropolitan area of San Juan, Puerto Rico. Low-income residents in Puerto Rico are considered to be those in the lower 50% of the population income. 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" (www.huduser.org, 2009). Family size is another important aspect to take into account when reviewing low-income homes and the annual salaries of those residents.

2.1.1 Demographics: Typical Low-Income Families

The average size of families in Puerto Rico has changed drastically in the last fifty years. To quote 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" (www.ifhp.org, 2008).

When looking at the data collected by the U.S. census from 2009, the average income for a three family home in the United States was $64,597. Comparatively, the average income for a three family home in Puerto Rico was only around $23,000 (www.justice.gov, 2009).

Among the low-income residents in metropolitan San Juan, most have jobs associated with the tourism industry. San Juan's tourism industry is massive due to the annual high volume of visitors. "Tourism produces 7% of the island's GNP and employs more than 60,000 islanders, a figure that is rapidly increasing" (www.nationsencyclopedia.com, 2010). The tourism jobs that these low-income residents hold do not provide significant hourly wages; however, they do provide a means of providing for one's family.

2.1.2 Definition of a Low-Income Residence in San Juan

For the purpose of this study, we will be evaluating low-income single and multi-family homes, and small apartments including Section 8 housing units. Low-income residences can prove to be difficult to define. It is challenging to determine where to draw the line that defines a low-income home. 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" (www.ifhp.org, 2008). It is also important to understand that "affordable housing" may not necessarily always be low-income housing. Similarly, Section 8 housing is defined to be, "affordable housing choices for very low-income residences…allowing families to choose privately owned rental housing" (hud.gov, 2010). We address Section 8 housing units because several of them are located in and around the San Juan metropolitan area. Low-income residences are located throughout the entire island of

Puerto Rico; but, as stated previously, 31% of the island's population resides in the city of San Juan. Consequently, this investigation focuses solely on the low-income residences of metropolitan San Juan.

2.1.3 Problems Associated with Low-Income Residences

Puerto Rico is struggling through an economic recession that led to the increased price of energy on the island. Although energy prices have risen, citizens 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, we learned that typical low-income residences in Puerto Rico are equipped with everyday electrical appliances. This includes, but is not limited to: laundry washers and dryers, standard lighting devices, air conditioners, computers, televisions, and assorted kitchen appliances (i.e. refrigerators and microwave ovens). Unlike the mainland of the US, these devices do not always include heating devices and dishwashers. Due to the low fluctuating temperatures in Puerto Rico's climate zone, heaters are not needed and dishwashers are considered a luxury to low-income residents. One problem is the inefficient degree of energy consumption in these low-income residences. As the cost of energy increases due to the rising price of foreign oil and Puerto Rico's dependence on this energy source, low-income citizens are struggling to afford the cost of energy.

2.2 Energy Generation, Uses, and Simulations

Puerto Rico relies almost completely on imported fuel for energy generation. It is also 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. Undoubtedly, the development of energy simulations will be a key tool for the PREAA in an effort to conserve energy in Puerto Rico.

2.2.1 Dependency on Fossil Fuels

Puerto Rico, like most island nations, has a dependency on fossil fuels for the generation of energy (Weisser, 2004). Over the past decade, oil prices have spiked 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. Luis M.B. Jimenez, the executive director of Puerto Rico's Energy Affairs Administration (PREAA), stated that Puerto Rico is 98% dependent on fossil fuels for energy generation and this makes energy prices on the island very expensive (Luis Jimenez, Personal communication, 2009). There is also 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 fuel varies wildly with changes in market conditions. Energy production rates from various generation sources can be seen below in *Table 1* from the U.S. Energy Information Administration.

Table 1: Energy Production Rates from Various Generation Sources in Mills ($0.001) per Kilowatt hour (Source: The U.S. 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 the course of years or decades. 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.

2.2.2 Household Energy Use

Most household energy use is attributed to the heating and cooling of the interior of the house. In Puerto Rico, we will investigate the cooling of interior spaces due to the tropical climate. Almost 24% of home energy use in a tropical climate is credited to air conditioning (www.energystar.gov, 2009). Of course, the energy efficiency of other household appliances is an important factor in household energy consumption. Other appliances, such as refrigerators, washing machines and dryers, computers, and televisions are the biggest consumers in a household respectively; a refrigerator uses approximately five-times the energy of a typical television (Department of Energy, 2008). As a reference, 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). We expect consumption to be lower in the residences that are examined in Puerto Rico due to family size and household income. However, electricity in Puerto Rico averages $0.18-0.20 per kWh (J. Maduro, Personal Communication, February 8, 2010), meaning annual energy expenditures are relatively close in actual dollars to the average U.S. household annual energy expenditure. Energy is used for a multitude of activities in any given household. In recent years, over-consumption of energy has been addressed by many governmental and environmental agencies.

Space Cooling

Because of Puerto Rico's location in the tropics, the cooling of a residence, also known as space cooling, is common. In San Juan, the use of air conditioners is widespread (J. Maduro, Personal Communication, February 8, 2010). 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. Simply cleaning the coils of a dirty air conditioner can greatly improve its performance consequentially requiring less energy to effectively cool a room or dwelling. In sunny climates, window curtains are an effective means of blocking the sun’s radiation from entering a home. In most homes, the sun’s radiation is a major source of internal warming. In addition, partitioning rooms with curtains lowers the temperature of certain, more critical areas of a home without wasting energy cooling unused spaces. By using these simple 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, another key contributor to energy consumption, 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.

2.2.3 Energy Simulations

Energy simulations are useful tools to analyze the influence 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

As previously mentioned, 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).

Within the realm of the 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 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 collapse, these factors are undoubtedly important in accurately simulating energy consumption.

2.3 Existing Energy Conservation Guidelines

The understanding of existing energy codes and rating systems, such as those in the United States and other regions of the globe, is relevant for our project in Puerto Rico. Our sponsor has requested the creation of a set of recommended efficiency techniques that could lead in the development of an energy conservation code for the island, similar to the International Energy Conservation Code (IECC). To create such guidelines, we will explore the features of the IECC, along with other rating systems found in the United States, such as the Leadership in Energy and Environmental Design (LEED) and Residential Energy Services Networks (RESNET) rating systems.

2.3.1 International Energy Conservation Code

An understanding of the 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.

An important feature of the IECC is that its 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). Our group will observe these methods, or the lack thereof, in the low-income Puerto Rican housing. Incorporating suggestions from this project's final report into a similar code for Puerto Rico could greatly increase overall energy efficiency on the island.

2.3.2 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 our work in Puerto Rico to identify energy saving techniques and improvements that could be made to existing low-income 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 our study will be 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 when 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 low-income residences of Puerto 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 usage through the LEED guidelines will guide our team in evaluating the energy usage of low-income 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 that will be investigated in our study in Puerto Rico.

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.

2.3.3 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.

The score of 0 means that the residence does not require any purchased energy for operation. For our project in Puerto Rico, the focus is to provide energy efficiency recommendations so 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 rater recommendations for cost-effective improvements to the buildings.

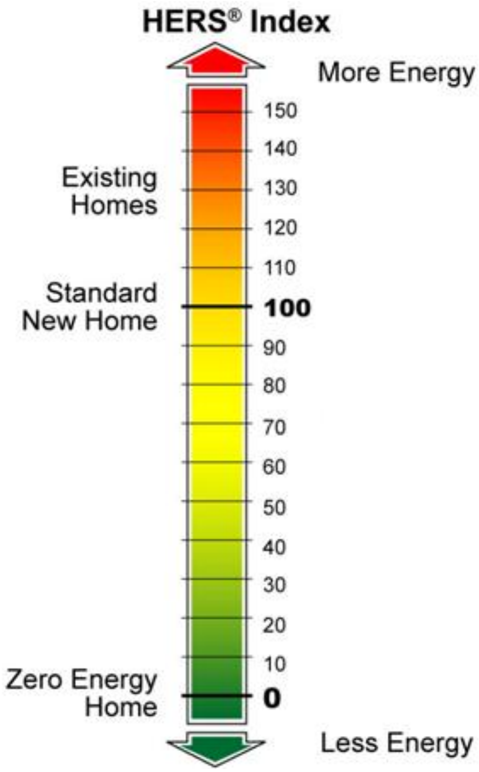

Figure 1: RESNET HERS Index (Source: natresnet.org, 2010).

The Home Energy Rating System Index is calculated using advanced energy simulation modeling. The modeling techniques employed by this rating system may be useful to the PREAA 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 a continuous process. The exploration of the development of these standards is necessary in order to understand how Puerto Rico may begin to develop energy guidelines for its low-income residents. RESNET accepts proposals for new or revised standards from any interested parties. These modifications or additions are then reviewed by RESNET's Standing Committee who publishes the comments online for public comment for a minimum of thirty days. The public comments are 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).

The Puerto Rico Residential Energy Affairs Administration indicated that understanding the RESNET HERS Index is required background for this project. Our group will incorporate RESNET's energy usage guidelines and process for developing energy standards into our project in Puerto Rico. This effort may enhance the PREAA's understanding of the feasibility and development of such energy rating systems in Puerto Rico.

2.4 Energy Saving Alternatives and Practices

This section outlines the capability of alternative energy in Puerto Rico as determined by the PREAA, energy efficiency programs in similar climate zones, existing case studies, and incentive programs and governmental support in Puerto Rico.

2.4.1 Capability of Alternative Energy in Puerto Rico

In 2008, the Puerto Rico Energy Affairs Administration 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" (PREAA, 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 (PREAA, 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. Despite this impressive statistic, this technology is very expensive and not always a viable option for low-income residences.

2.4.2 Energy Efficiency Programs in Puerto Rico

Although there are no guidelines for energy conservation in low-income housing in Puerto Rico, the PREAA 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 our focus and the government document 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 directly to our study as we hope to recommend strategies to reduce the long-term electric costs for the low-income residents (PREA, 2009).

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 PREAA 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 asked 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 or 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).

Throughout the world, and particularly in Puerto Rico, 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 residential 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 PREAA is in the process of developing a plan to provide rebates to residents who purchase ENERGY STAR rated products (Guidance to Dealers and Suppliers of Goods on ENERGY STAR Program Rebate, 2010).

Additionally, 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 PREAA will fund the installation of air conditioners in eligible low-income housing. 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).

2.4.3 Energy Efficiency Programs in the United States and Similar Locations

The energy conservation and efficiency programs in Florida, a state that is partly in the same climate zone (Zone 1, as outlined in the IECC), were investigated in this review. It was noted that very little of the funding from the WAP went toward making improvements in residences to make them more energy efficient. The only program noted in this study is the Weather Care program from the Tampa Electric Company that offers free home improvements to weatherize home for seniors 60 years or older and of a fixed income. All other programs focus on helping low-income families pay their 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

As energy conservation and efficiency concerns continue to grow, there exist numerous case studies conducted around the world regarding these prevalent issues. Reviewing these case studies, particularly those regarding residential energy and similar climate regions as Puerto Rico, has yielded relevant energy efficiency guidelines for the development of this project.

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 that could aid in 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 in Puerto Rico parallel those of Bermuda residents.

The Bermuda study identified an array of viable options to increase energy efficiency in Bermuda. One of the major solutions to the energy issues on the island 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 guidelines that our group will establish for the low-income 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. Some of the major conservation strategies pertaining to residential energy that have been identified in supporting literature include: investing in alternative sources such as wind, reducing the use of household appliances and air conditioning systems, and analyzing the insulation properties of new and existing residences. 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 pertinent 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 low-income residences and analyze their contribution to thermal heat storage and air conditioning requirements.

2.5 Summary

This literature review explores numerous topics pertaining to our residential energy project in Puerto Rico. In order to devise valuable energy efficiency recommendations, it is important to understand the definition of a Puerto Rican low-income housing unit and be familiar with the economic status of the residents living there. 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. The study of existing energy codes, building codes, energy efficiency efforts in similar climate regions, and governmental energy initiative programs provide insight into the potential energy efficiency techniques that could be used in Puerto Rico. The research efforts pertaining to these topics aid in the development of our methodology and completion of our objectives.

Chapter 3: Methodology

The goal of this project is to develop energy efficiency recommendations to aid in the creation of a residential energy conservation code and home efficiency rating system for Puerto Rico. Specific objectives of our project include determining current energy use in low-income Puerto Rican homes, formulating an energy-efficient low-income housing model, and developing a list of practical suggestions pertaining to alternative energy forms and techniques. This process will include surveys, interviews, audits, and energy use data collection, which are specifically designed to complete each of the identified objectives. The methodology process is presented in *Figure 2*. Notice the overall goal of the project is outlined in red followed by corresponding objectives and methods.

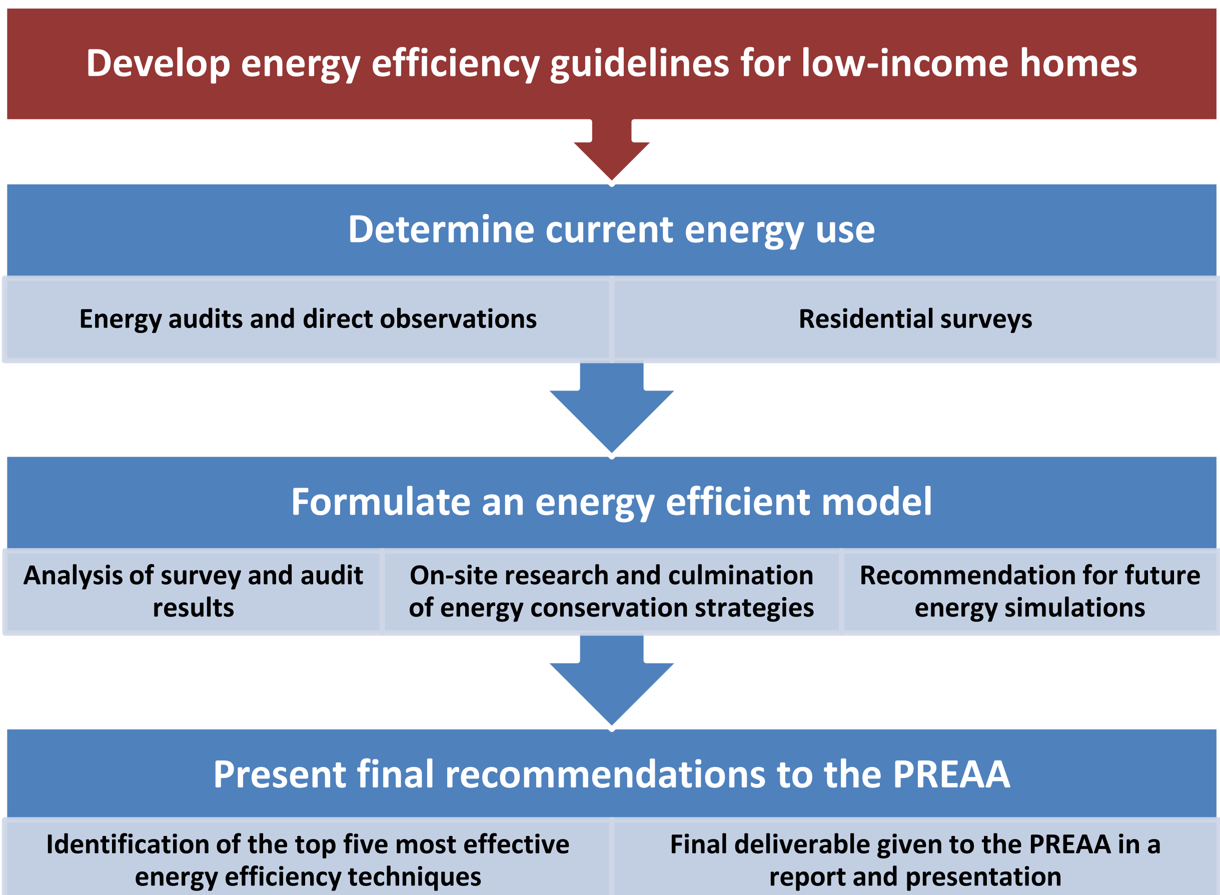

Figure 2: Flow Chart of Methods Process

3.1 Determination of Current Energy Use

The first objective of our project is to determine the current energy use of low-income residences in metropolitan San Juan. This phase of our project provides a means to evaluate the existing state of residential energy consumption in the low-income sectors of the island. The process for determining the energy use involves performing energy assessments for these areas through field visits and surveying the residents of these low-income housing units.

3.1.1 Energy Audits and Direct Observations

To determine existing energy use in the low-income housing of San Juan, a general understanding of the energy consumption features of these residences is required. Walk-through energy audits are an economical, time-efficient and effective means of gathering this data. This process is observational and will entail field visits to the low-income housing units, noting important energy characteristics. These audits will be performed in groups of two project team members accompanied by government provided support staff. The audits include a determination of recent home updates through surveys of homeowners and landlords, as well as walk through observations. Notable characteristics pertinent to the audit include 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 ENERGYSTAR appliances). A comparison of the notes from our audits to those energy efficient practices identified in existing literature, presented in Chapter 2, will provide an understanding of the specific energy efficiency problems facing the residents. The audit results will be recorded as they are performed. They will itemize potential areas for energy efficiency improvements. Refer to Appendix A to view the audit form.

3.1.2 Residential Energy Surveys

During the auditing process, a brief survey will be handed to the homeowner in order to generate a general demographic profile of the population, assess trends in their current energy usage techniques, and develop an understanding as to their awareness for energy conservation practices. Surveying low-income residents provides insight to the residents' knowledge of energy conservation methods and their access to energy efficiency products. In order to accommodate for any language barriers, it is necessary that the surveys be written in both English and Spanish. The surveys will be distributed to the residences where we will perform audits (as specified by the PREAA) and will consist of one survey per household. Refer to Appendix B to view the survey form.

3.1.3 Usage of Data and Analysis

Organization of the data from the energy audits and surveys will be accomplished by grouping the data according to household occupancy. In analyzing the field data, our group will investigate overall trends and develop a general representation of energy use for the low-income population of San Juan. It is understood that energy usage varies between residences; however, the collection of data from a large sample will help to ensure an accurate model for the typical energy usage of the low-income population. Using the data from the surveys and audits, our group will establish an energy use model that lists common sources of energy consumption and the extent of energy usage in the low-income residences.

3.2 Formulation of an Energy Efficient Model

The energy efficiency of any dwelling is dependent on a number of variables that include construction materials and methods, behavior of the inhabitants, use of electrical appliances, and economic circumstances. Using the existing energy consumption trends found in the surveys and audits along with on-site research, an energy efficiency model will be developed. The model will consist of information outlining recommended energy conservation strategies for the low-income residences in Puerto Rico. This information will be suitable for a pamphlet that may be produced and distributed by the PREAA.

3.2.1 Analyzing and Interpreting Survey and Audit Results

After visiting a number of homes and collecting data though energy audits and resident surveys, the goal is to find trends in the data. Our group will look for a relationship between household characteristics and energy usage within the low-income residences. Such characteristics may include, but are not limited to: the number of people residing in the home, number/type of appliances, lighting fixtures, employment hours, air conditioner status (number, control settings, and maintenance) and any energy efficiency strategies that may already be in place. The data will be input into a spreadsheet and organized by household occupancy. Thorough examination of the data will provide insight regarding the current energy use in a low-income home.

Successful implementations of efficiency strategies are strongly dependent on resident awareness of conservation measures. One important aspect is the residents' perception of their accessibility to energy efficient appliances. From the initial survey, we will understand residents' knowledge of and willingness to adopt conservation techniques. The analysis of the data collected from the survey will determine where the PREAA must focus its attention: whether it is simply to promote awareness of efficiency strategies or to sponsor incentives to encourage the use of more efficient appliances.

3.2.2 Culminating Energy Efficiency Strategies

Formulation of the energy efficiency strategies for the energy model for Puerto Rico will be based upon the analysis of existing energy consumption and on-site research. Once the trends in the current energy consumption are established, our group will seek additional information regarding energy conservation within the offices of the PREAA. In speaking with our sponsor, it is evident that this on-site research at the PREAA will be beneficial to developing the most effective energy conservation guidelines. The background research provided within Chapter 2 of our proposal documents our awareness of related energy conservation techniques; however, further research conducted at the PREAA may further enhance our knowledge of energy conservation practices available in Puerto Rico. Accumulating the background information within this proposal, the field work results, and the on-site research will allow for the development of an energy efficient model. As previously mentioned, this model will consist of information outlining practical energy conservation techniques that could be employed in the low-income residences of Puerto Rico. The distribution of this information to the public could be accomplished through the creation of a pamphlet by the PREAA.

3.2.3 Recommendations for Future Energy Simulations

Our team was asked to create a foundation for energy simulations that the PREAA would like to develop in the future. With knowledge of the current energy use and potential energy conservation techniques, our group will be able to provide the PREAA with a recommendation for the creation of an energy efficient model. At this point in our research, a bottom-up energy simulation seems to be the most feasible and practical for application in San Juan. This kind of simulation uses the basic characteristics of a household as inputs. It then outputs extrapolated results representative of residential energy use in specified regions. Our group will not be designing the energy simulation; however, we will be providing useful information regarding current energy use and potential energy strategies for which this model could be based upon.

3.3 Presentation of Final Suggestions for the PREAA

Once our group completes the aforementioned steps of the methodology, we will formulate a final listing of key recommendations to present to the PREAA. This listing will include the top five most effective techniques that low-income residents can implement to conserve energy within their housing units. Through the identification of these top energy efficiency guidelines, we will take into careful consideration the current problems associated with the existing energy consumption, as identified in the energy audits and energy use surveys. Many of the energy efficiency recommendations presented in the energy efficient model may be incorporated into this final list. Using the data collected and analyzed, our group will develop this final listing of recommendations for potential PREAA guidelines in developing a residential energy conservation code and rating system.

The final deliverables consist of a final report and presentation to the PREAA. The material within the report will include survey and audit results, a model for current energy use in the low-income residences of San Juan, a model for an energy efficient home, and a final listing of the most critical residential energy efficiency recommendations for Puerto Rico. These final products will be the direct result of the methods outlined within this chapter.

Chapter 4: 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 homes. There are many simple techniques that can reduce residential energy consumption. The methods outlined in Chapter 3 will identify how energy is used within low-income homes and allow us to develop the steps that can be taken to reduce superfluous energy use.

The background information obtained from our literature review provides insight into the technical and social aspects pertaining to our project. Topics of interest within the literature review included: the characteristics of low-income housing and residents in San Juan, energy use and consumption, related energy simulations, existing energy conservation guidelines, and the capability of alternative energy and energy saving practices in Puerto Rico. Due to potential language barriers and invasion of privacy concerns, methods were developed with care to ensure that they would effectively complete our objectives while protecting the rights of the Puerto Rican residents. Key components of our methodological procedure consist of performing energy audits and energy use surveys to determine current energy use, formulating an energy efficient model, and developing the most effective recommendations for residential energy efficiency.

This project has significance to each member of our team as well as the PREAA and residents of Puerto Rico. We feel that each of us benefits from this project through the experience of working outside the classroom on a "real world" problem. By working with the PREAA to achieve its goal of addressing energy efficiency in low-income residences, we will gain valuable experience working within a professional organization. If our recommendations are adopted, residents may save money on their electric bills. Meanwhile, the PREAA may further their progress toward the goal of reducing energy consumption in Puerto Rico. The seven weeks of research and methodology development have thoroughly prepared us for the implementation of our project. Discussions with both Jan Maduro, our liaison from the PREAA, and Alexis Miranda, the project engineer from the PREAA, have solidified our confidence, as well as stimulated our excitement, in travelling to Puerto Rico to complete this project.

References

Bermuda Department of Energy (2010, February 9). Energy green paper: A national policy consultation on energy, (2009). Bermuda: Bermuda Department of Energy. Retrieved from http://2009_bermuda_energy_green_paper.pdf

Camacho, Felix P. (2010, February 6). State energy program assurances, (2009). United States Department of Energy. Retrieved from http://www.energy.gov/recovery/documents/Camacho_Guam.pdf

Database of State Incentives for Renewables and Efficiencies (2010, February 15). Puerto Rico - state energy program - building energy efficiency retrofit rebate program. United States Department of Energy. Retrieved from http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=PR18F&re=1&ee=1

Encyclopedia of Nations (2010, February 10). Puerto Rico - country overview. Retrieved from http://www.nationsencyclopedia.com/economies/Americas/Puerto-Rico.html

Guam Energy Office (2010, February 4). Energy lighting audit. Retrieved from http://www.guamenergy.com/main/index.php?pg=pr.energy.lighting

International Federation of Housing and Planning (2010, February 8). Affordable housing in Puerto Rico, (2008). Retrieved from http://www.ifhp.org/component/option,com_docman/task,doc_download/gid,9/Itemid,82/

Kunchornrat, A., Namprakai, P., & du Pont, P. T. (2009). The impacts of climate zones on the energy performance of Thai buildings. *Resources, Conservation and Recycling, 53*, 545-551.

Puerto Rico Energy Affairs Administration (2010, February 12). Assistance program the air in Puerto Rico. Retrieved from http://translate.google.com/translate?hl=en&sl=es&u=http://www.aae.gobierno.pr/&ei=y3hzS8rFDZWlnQfRzOWYCw&sa=X&oi=translate&ct=result&resnum=4&ved=0CBIQ7gEwAw&prev=/search%3Fq%3Dpuerto%2Brico%2Benergy%2Baffairs%2Badministration%26hl%3Den%26rls%3Dcom.microsoft:en-us:IE-SearchBox

Puerto Rico Energy Affairs Administration (2010, February). Financial assistance funding opportunity announcement for nonprofit community base organizations, (2010). PREAA. Retrieved from http://translate.google.com/translate?hl=en&sl=es&u=http://www.aae.gobierno.pr/&ei=y3hzS8rFDZWlnQfRzOWYCw&sa=X&oi=translate&ct=result&resnum=4&ved=0CBIQ7gEwAw&prev=/search%3Fq%3Dpuerto%2Brico%2Benergy%2Baffairs%2Badministration%26hl%3Den%26rls%3Dcom.microsoft:en-us:IE-SearchBox

Puerto Rico Energy Affairs Administration (2010, February). Guidance to dealers and suppliers of goods on ENERGY STAR program rebate, (2010). Retrieved from http://translate.google.com/translate?js=y&prev=_t&hl=en&ie=UTF-8&layout=1&eotf=1&u=http%3A%2F%2Fwww.aae.gobierno.pr%2F&sl=es&tl=en

Puerto Rico Energy Affairs Administration (2010, February). Guidelines on energy conservation measures in government agencies, (2009). Retrieved from http://translate.google.com/translate?hl=en&sl=es&u=http://www.aae.gobierno.pr/&ei=y3hzS8rFDZWlnQfRzOWYCw&sa=X&oi=translate&ct=result&resnum=4&ved=0CBIQ7gEwAw&prev=/search%3Fq%3Dpuerto%2Brico%2Benergy%2Baffairs%2Badministration%26hl%3Den%26rls%3Dcom.microsoft:en-us:IE-SearchBox

Residential Energy Services Network (2010, February). 2009 RESNET annual report. Oceanside, CA: Residential Energy Services Network. Retrieved from http://www.natresnet.org/about/reports/Annual_Report_2009.pdf

Residential Energy Services Network (2010, February). Residential energy services network. Retrieved from http://www.natresnet.org/about/resnet.htm

Rivera, Magaly (2010, February 6). Welcome to Puerto Rico, (2010). Retrieved from http://www.topuertorico.org/city/sanjuan.shtml

Seligman, C., & Darley, J. M. (1977). Feedback as a means of decreasing residential energy consumption.. *Journal of Applied Psychology*, *62*(4), 363-368.

Swan, L. G., & Ugursal, V. I. (2009). Modeling of end-use energy consumption in the residential sector: A review of modeling techniques. *Renewable and Sustainable Energy Reviews*, *13*(8), 1819-1835.

United States Department of Energy (2010, February 4). About ENERGY STAR. Retrieved from http://www.energystar.gov/index.cfm?c=about.ab_index

United States Department of Energy (2010, February 1). DOE: Building energy codes (2009). Retrieved from http://www.energycodes.gov/codedevelop/

United States Department of Energy. (2008). *Energy savers booklet.* Washington D.C.: U.S. Department of Energy Office of Energy Efficiency and Renewable Energy.

United States Department of Energy (2010, February 10). Energy savers: Your home, (2010). Retrieved from http://www.energysavers.gov/your_home/

United States Department of Energy. (2010, February). Obama administration delivers more than $101 million for weatherization programs in Guam and Pennsylvania, (2009). Retrieved from http://www.energy.gov/news2009/7835.htm

United States Department of Energy (2010, February). Residential requirements of the 2009 International Energy Conservation Code. Washington, DC: United States Department of Energy. Retrieved from http://www.eere.energy.gov/2009%20iecc%20residential.pdf

United States Department of Health and Human Services (2010, February 1). FY 2009/2010 low-income energy programs. Retrieved from http://www.liheap.ncat.org/profiles/Florida.htm

United States Department of Housing and Urban Development (2010, January 20). Housing choice voucher program (section 8). Retrieved from http://portal.hud.gov/portal/page/portal/HUD/topics/housingchoicevoucherprogramsection8

United States Environmental Protection Agency (2010, February). A guide to energy efficient heating and cooling, (2009). Retrieved from http://www.energy star.gov/ia/partners/publications/pubdocs/HeatingCoolingGuide%20FINAL_9-4-09.pdf

United States Environmental Protection Agency (2010, February 10). Properly sized room air conditioners, (2009). Retrieved from http://www.energystar.gov/index.cfm?c=roomac.pr_properly_sized

United States Green Building Council. (2009). *Green building and LEED core concepts guide*. Washington, DC: U.S. Green Building Council.

United States Green Building Council (2010, February 4). United States Green Building Council. Retrieved from http://www.usgbc.org/DisplayPage.aspx?CMSPageID=222

United States Trustee Program (2010, February 9). Census bureau median family income by family size, (2009). Retrieved from http://www.justice.gov/ust/eo/bapcpa/20090315/bci_data/median_income_table.htm

Weisser, D. (2004). On the economics of electricity consumption in small island developing states: A role for renewable energy technologies? *Energy Policy*, *32*(1), 127-140.

Appendix A: Energy Audit Form

Energy Audit

General:

Names of persons performing audit: ____

Date: ________________________ Time: ________________________

Current Energy Saving Procedures: (Ex: Home renovations, use of ENERGYSTAR appliances)

____

Current Conservation Techniques Implemented: (Ex: Running air conditioners only at certain times, air drying clothing) ____

Household information:

Household size: ____

Daily Occupancy Profile:

100%

0%

12 AM 6 AM 12 PM 6 PM 12 AM

100%

0%

Sunday Monday Tuesday Wednesday Thursday Friday Saturday

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 (Please circle the correct time range):

>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: _________________________

Foundation material: _________________________

Building material: _________________________

Number of Entrances: _________________________

Number of Windows: _________________________

Basement: Y / N

Attic: Y / N

Condition of insulation around windows: Good Fair Needs Improvement Uninsulated

Condition of insulation around foundation: Good Fair Needs Improvement Uninsulated

Condition of insulation of water heater: Good Fair Needs Improvement Uninsulated

Cooling:

Is there air conditioning? Y / N

What type of air conditioning in residence? Central AC Window Units None

If window units, how many units, what thermostat setting are they set at, and where are they located?

Unit #	Thermostat Setting	Location

If central air, are there different air conditioning settings for each room? Floor? Explain, ____

Number of fans: _________________________

Notes (types, location) _________________________

Lighting:

Number of fixtures: _________________________

Number of Incandescent light bulbs: _________________________

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

Laundry:

Washer: Y / N / Energystar

Dryer: Y / N / Energystar

Kitchen:

Refrigerator: Y / N / Energystar

Oven: Y / N / Energystar

Coffee Maker: Y / N / Energystar

Microwave: Y / N / Energystar

Toaster oven: Y / N / Energystar

Other appliances (Please specify): ____

Other:

Number of televisions: ___________________________________

Number of computers: ___________________________________

Other observations: ____

Appendix B: Energy Use Survey

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 PREAA and Worcester Polytechnic Institute in Worcester, Massachusetts.

Please mark the appropriate answer:

1. How many people live in your residence?

- ○ 1-2
- ○ 3-4
- ○ 5-6
- ○ 7+

2. How many of those people are employed?

- ○ 0
- ○ 2
- ○ 3
- ○ 4
- ○ 5+

3. In what industries do the people in your residence work?

- ◉ Unemployed
- ○ Service Industry
- ○ Tourism
- ○ Other: ______

4. What hours do the people in your residence work?

- ○ 6am-12pm
- ○ 12pm-6pm
- ○ 6pm-12am
- ○ 12am-6am

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5. On average how many hours a week do the people in your residence work? Please indicate the number of people who fit into each category

- 0-10
- 10-20
- 20-30
- 30-40

Household Energy Use

6. How many air conditioners do you have?

- I do not have one
- 1
- 2
- 3
- 4
- 5+

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

- Not Applicable
- Less than 2
- 2-6
- 7-12
- 12+

8. When is your air conditioner usually turned on?

- N/A
- 6am-12pm
- 12pm-6pm
- 6pm-12am
- All the time

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

- Very Cold (less than 67°F / 19°C)
- Cold (67-70°F / 19-21°C)
- Mild (above 70°F / 21°C)

10. Do you have a clothes washing machine?

- Yes
- No

11. Do you have a clothes drying machine?

- Yes
- No

12. How many loads of laundry do you machine wash a week?

- N/A
- 1
- 2
- 3
- 4
- 5+

13. How many refrigerators for you have?

- 0
- 1
- 2
- 3+

Energy Conservation Techniques

14. Have you heard of ENERGYSTAR?

- Yes
- No

15. How many ENERGYSTAR appliances do you own?

- 0
- 1
- 2
- 3
- 4+

16.Would you purchase ENERGYSTAR appliances if there was a rebate program?

- Yes
- No
- I am not sure

17. Have you implemented any of the following energy conservation methods suggested by the PREAA?

- [ ] 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 unplug 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 and televisions
- [ ] Use ENERGYSTAR rated appliances