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Feasibility of a Smart Grid on Nantucket

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A Worcester Polytechnic Institute Interactive Qualifying Project

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Abstract

Nantucket residents pay uncommonly high electricity rates because delivery of electricity to the island is costly and demand for it fluctuates widely by season. Accordingly, the goal of this report is to assess the feasibility of various smart grid scenarios and conservation initiatives that could reduce the cost and consumption of electricity island-wide. Based on our analysis of the associated benefits and costs, we concluded that a smart grid could conservatively save island residents up to $500,000 annually, and pay for itself in only five years. Understanding the pattern of use on Nantucket and the potential of smart grids, we recommend seeking further consultation.

Executive Summary

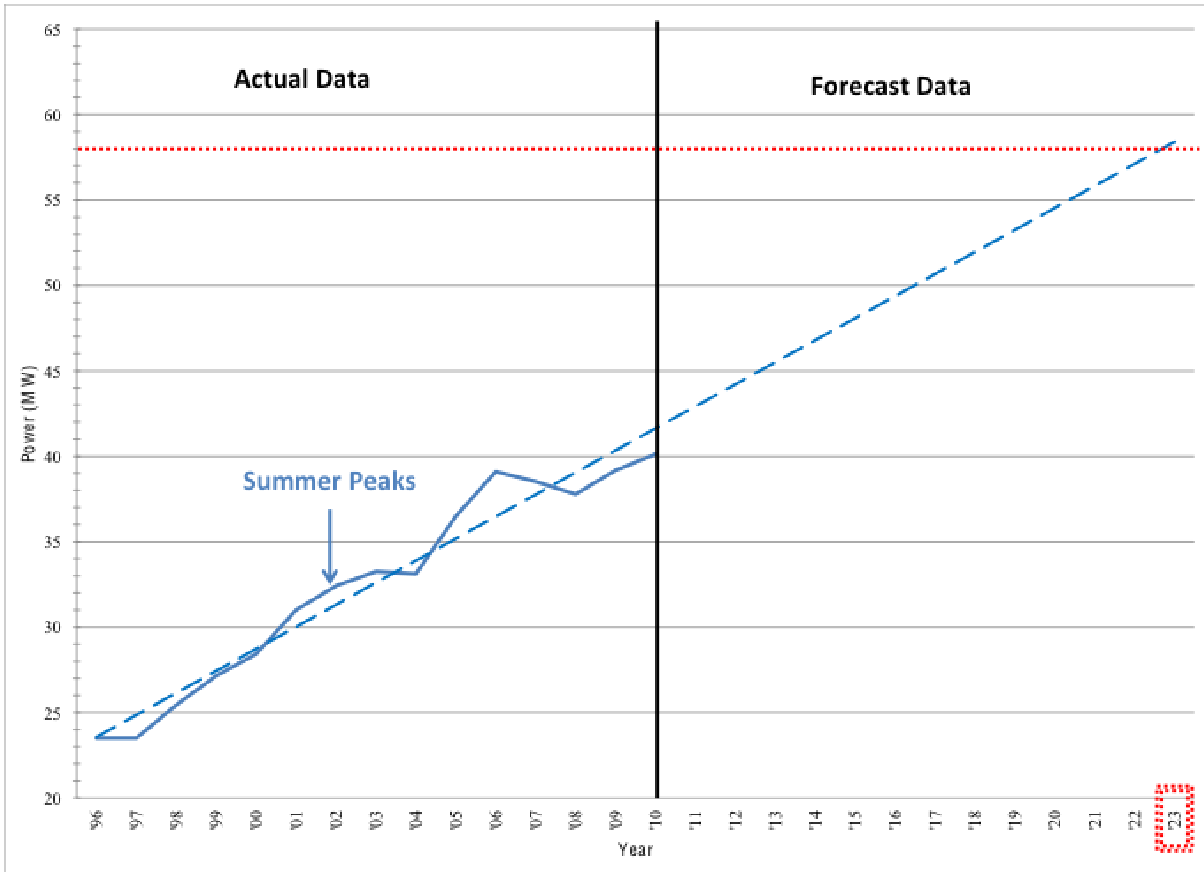
Nantucket residents pay uncommonly high electricity rates, because delivery of electricity to the island is costly and demand for it fluctuates widely by season. Nantucket's electricity rate (18.4 cents/kWh) is nearly 15% above the average rate for residents elsewhere in Massachusetts and 1.5 times the national average rate (National Grid, 2010eNational Grid, 2010a).

A major focus of the Nantucket Energy Study Committee (NESC) is how smart grid technology might reduce the cost and consumption of electricity island-wide. This Interactive Qualifying Project explores this prospect by analyzing the feasibility of various smart grid scenarios and conservation initiatives and quantifying associated benefits and costs.

Electricity is delivered to Nantucket via two submarine transmission cables, which span 26 miles from Cape Cod to Nantucket and both cables supply up to 70 MW of power (Nantucket Electric, 2010). The expense of this infrastructure partly accounts for Nantucket's uncommonly high electricity rates. Although island-wide electricity demand peaked at only 40 MW in 2010, electricity usage has trended upward over time, necessitating an even higher capacity in August, the peak month of tourism on Nantucket (see Figure 1). The population on Nantucket fluctuates from approximately 12,000 people in the off-season to 60,000 people in August. The large number of people on Nantucket in the summer months, including year-round residents, seasonal homeowners, an influx of weekend trippers and daytime visitors cause electricity usage to spike to a degree not seen in most communities.

Until 1996, electricity was generated by an approximately 20 MW Electro Motive Diesel (EMD) power plant located in Nantucket's Candle Street historic area (Business Wire, 1996). A succession of brownouts and blackouts prompted the installation of Nantucket's first 35 MW cable by National Grid, Nantucket's utility company, which made it possible to shut down the EMD plant and improve electric supply reliability and rate stability (P. Morrison, personal communication, 2010).

By 2005, Nantucket's energy needs had surpassed the capacity of this 35 MW cable (see Figure 1). National Grid installed another cable costing $41 million and imposed a 2.958 cents /kWh surcharge onto delivery rates from June to September and a 1.834 cents/kWh from October to May to pay off the cables (Freshwater, 2010; National Grid, 2010e).



Yearly power peaks from 1996 to 2010

Following installation of this second cable, the Town of Nantucket recognized that island-wide energy consumption would inexorably rise (see Figure 1) and established a committee to research options to reduce electricity costs on the island (A. Kuszpa, personal communication, December 2, 2010). The Nantucket Energy Study Committee has been instrumental in promoting efforts for renewable energy, electricity conservation, and potentially a smart grid. Specifically, the committee has facilitated the installation of 8 MW of solar energy and a 1.5 MW wind turbine adjacent to Nantucket High School's 100 kW wind turbine success. In order to integrate these renewable energy resources, the NESC has promoted interest in smart grid technology.

For readers unfamiliar with smart grid technology, these systems actively communicate power input and output information and distribute power accordingly between power production facilities, transmission and distribution systems, homes, and appliances. They enable consumers to make informed choices, and to participate actively in modifying their energy consumption rates based on information and control options provided (US Department of Energy, 2009b). Smart grid systems are designed to conserve energy, reduce peak demand, enable bidirectional flow of energy, and provide a two-way communication system between the end-user and the utility (U.S. Department of Energy, 2008).

A smart grid would offer Nantucket a wide range of possibilities, most importantly the ability to lower the upward trend in electric power peaks[1]. The compelling rationale for postponing the need for a third National Grid transmission cable is to postpone a further electric rate surcharge to consumers for covering the major ($50 million) capital costs of building the cable.

Beyond peak reduction, smart grids also enable power utilities to "net meter"[2] the electricity produced locally by renewable energy resources. The current plans for renewable energy could be beneficial: solar would produce the most energy during sunny summer days, corresponding with power peaks caused by air conditioning, whereas wind would produce a majority of its' energy at night and during the winter, corresponding with winter space heating consumption.

From our analysis of potential monthly renewable power generation over the course of a year, we concluded that the renewable energy load reduction would be relatively consistent at 1000 MWh annually. This will reduce the amount of electricity imported from the mainland, thereby postponing the need for a large capital investment for a third submarine cable.

Another way to delay that capital investment would be to promote electricity conservation through island-wide programs. We estimate that conservation with 100% participation could save Nantucket residents up to $3 million annually, including initial costs. The prospect for 100% participation is highly improbable, but participation by 10% to 20% of Nantucket residents would make a meaningful difference. Specifically, we explored scenarios envisioning 10% to 20% of households replacing all incandescent light bulbs with CFLs, installing energy saving thermostats, and regularly unplugging their electric appliances.

Smart grids are another option for trimming energy use. Based on pilot studies and the

1 Electric power peaks are caused by the normal "rhythms" in a typical household. Peaks normally show up in the morning, nights, and on weekends (Hargreaves, 2010). Peaks drive up the demand for more expensive energy, which drive up the costs of electricity.

2 Net metering allows a consumer who is generating electricity through solar wind or other means to sell their excess power back to the grid.

opinions of experts in the field, a smart grid might reduce 5% to 20% of electricity per year. The payback period could vary from 10 to 30 years--or much less if other energy consumption reduction practices were put in place such as increased use of renewable energy or greater energy conservation.

The implementation process for smart grids would begin with negotiations with the utility company—National Grid owns the grid and therefore must be a partner. If Nantucket wanted to install a smart grid it must negotiate rates with its utility. Specifically, time-of-use (TOU) rates[3] play a large role in how smart grid will be perceived by the public. If peak electric rates are high and off-peak rates are very low the likelihood increases that peak demands will be reduced because consumers will recognize and respond to monetary incentives. The negotiation over rates may include a variety of solutions. Some of the cost of the smart grid could be dispersed over the consumer population through TOU rates, funded directly by grant money from the federal government or by the utility, which could be reimbursed in part by government funds and/or tax breaks. Smart grids are rarely ever funded privately or by local or state governments because the most incentives for smart grid still lie with the utility (D. Hurley & R. Tullman, personal communication, 2010). Though it is possible for the town and its residents to invest in a smart grid and reap a return from their investment, that return lies in the distant future through forestalling a third submarine cable.

In conclusion we recommend that Nantucket include National Grid in a smart grid installation because National Grid will provide the resources, information, and experience necessary to upgrade the grid. Additionally, we recommend that the town push forward on the proposed alternative energy projects, if proven cost-effective, and explore other opportunities for additional power generation. We also recommend that the town should encourage energy conservation programs educating the public about installing compact fluorescent lamps, installing programmable thermostats, and unplugging electrical appliances when not in use. If these recommendations are instituted together then the Island could see cost savings of approximately of $0.5 to $2 million per year on the typical energy costs.

[3] Utility companies offer time of use rates (e.g., higher rates at peak times such as during the daytime in summer) to encourage consumers to shift usage to off-peak times (e.g., night time).

Authorship

This Interactive Qualifying Project was written in collaboration with its authors: Andrew Beliveau, Mary Hesler, Stephen Jaskolka and K. Colyer Sigety. The entirety of the report, including all research, interviews, analysis, and conclusions, was completed over the course of 14 weeks during the authors' third year in pursuit of Bachelor's degrees at Worcester Polytechnic Institute. While individual authors wrote particular sections of this report, each section was reviewed and edited by all authors to ensure the report represents the group's assessment as a whole.

Disclaimer

This report was completed as a requirement for Worcester Polytechnic Institute and for the benefit of the Nantucket Energy Study Committee (NESC). The authors of this report are not professionals or experts in the field of smart grids or conservation, but rather used information gained from interviews with smart grid experts and local electricity users, as well as archival research to produce this report. The data used to create the various cost-benefit analysis situations was acquired from pilot studies, reports and from a limited amount of proprietary data obtained from Michael Peterson and Dave Fredericks of National Grid. The financial and electric usage assessments included in this report are estimates based on various stated assumptions and each includes margins of error with respect to actual results on Nantucket. The report also discusses the importance of the conservation of electricity and the inclusion of renewable energy sources as complimentary benefactors to the installation of a smart grid system. The report does not include any information regarding the concept of "green," and does not make any assertions about global warming or carbon emissions – the report should not be used as evidence in either context. While this report was completed in conjunction with the NESC, the team's report remained independent from the committee and as objective as possible throughout the entire project. Lastly, it is important to note that the opinions and conclusions made in this report are not reflective of Worcester Polytechnic Institute or any other institution that may have been involved with this independent study, and that all opinions and conclusions are only those of the undergraduate authors listed above.

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We would like to acknowledge the assistance of the individuals who took the time to provide our group with information and to interview with us. Thank you Debbie Dilworth from the Nantucket Tax Assessor's Office, Mark Avery of the Whaling Museum, Melissa Philbrick of ReMain Nantucket, Michelle Whelan of Sustainable Nantucket, Catherine Flanagan Stover of the Town Clerk's Office, Irene Larivee of the Town Finance Department, Dave Kanyock, the school's Facilities Director, and Jeff Willet, the Director of Public Works for the tremendous amount of information they provided our group. We would also like to thank Tim Milstead of Nantucket Island Resorts, Ron Foster of Marine Home Center, Peter McEachern of the Nantucket Yacht Club, Bob Gardner of the Wannacomet Water Company, Mike Forth of the Cottage Hospital, Jack Hayes of Our Island Home, and Kristina Jelleme of Toscana Corporation for the extensive interviews of which they each participated in. Further, we would like to acknowledge our appreciation for Paul F. Hesler of Chartis Insurance, Bob Patterson of the Town of Nantucket, Doug Hurley of Energy Economics Inc., John Edwards of Optimized Energy Networks, David Fredericks and Michael Peterson of National Grid, and Gregg Tivnan, the Assistant Town Manager, for all of their time, support, and patience exhibited to our project.

With fluctuating electricity use and a self-contained population, Nantucket remains a key player in the future of smart grid technology. We hope that the progress made by this report will provide the Nantucket Energy Study Committee with valuable information, analysis, and recommendations needed to expedite the process of determining the feasibility of achieving a smart electric grid on the island.

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Introduction

The United States, along with other developed and developing countries, is using more energy today than ever before. The series of transmission and distribution lines that carry electricity from power plants to every electric user in the nation, known as the electric grid, was initially built in 1896 and expanded thereafter. Much of the electric grid today remains as Nikola Tesla first described its design in 1888. Electric grids have been forced to meet an ever-growing demand, far exceeding the capacities that the nation's aging grid can appropriately manage.

Over the past 50 years, the world has experienced unprecedented technological growth, and electric grids have failed to keep pace with new modern challenges such as national power employment and distribution, and a substantially increased demand. The U.S. grid has become outdated, unreliable, and inefficient. Policy makers and utility companies have been searching for options to update the grid to buttress reliability, improve efficiency, and enhance accurate monitoring. Since 2005, a promising possibility has been development of a smart electric grid (Ma, 2010). A smart grid provides the communication and monitoring needed to manage electricity production, distribution and use instantaneously, and autonomously, donning the "smart" technology name. Recently, private and public investment has been pouring into smart grid technologies in an effort to revitalize the electric grid as well as incorporate energy efficiency thereby reducing energy production costs.

Nantucket Island, located 30 miles south of Cape Cod, currently pays a premium price for electricity, often attributed to the necessary cost of installing two undersea transmission cables. Nantucket also has among the highest energy costs in the nation because of extreme fluctuations in demand due to seasonal tourism and heightened consumer demand. Nantucket's year round population (as estimated by the US Census Bureau) is approximately 11,000, yet this figure increases fivefold during the months of July and August (Town of Nantucket, 2010a; Town of Nantucket 2010b). Electricity prices rise in the summer, when power utilities need to produce less efficient energy to meet the need for additional infrastructure, and the fluctuating demands throughout the year. Electricity users on Nantucket pay an average of 20% higher per kilowatt-hour than users elsewhere in Massachusetts (Department of Energy Resources, 2001-2010).

The Nantucket Energy Study Committee (NESC) is actively pursuing possible new energy programs that could moderate what Islanders must pay for electricity (W. Willauer, personal communication, 2010). The promise of increased efficiency and cost-savings makes smart grid technology a recommended option for Nantucket. Beyond efficiency and cost-savings, a smart grid system also could integrate renewable energy efficiently into the grid, enhance the grid's reliability by reducing outages, and lay a foundation for transitioning to investment into electric vehicles. Depending on what elements of smart grid technologies were to be installed, a smart grid on Nantucket Island could significantly reduce both the price of electricity and the amount used.

In order to decide whether smart grid technology is a suitable energy management and conservation approach for Nantucket, the NESC needed current energy usage data and information on the costs of installing smart grid systems to support a cost-benefit analysis of the initiative. This project collected records of the current electric usage of all relevant sectors, created an energy profile of the island, identified key smart grid models and programs, analyzed findings by comparing all potential methods, and formulated our ultimate smart grid recommendations to the NESC through a cost-benefit analysis of all energy initiatives. The project took into account the significant use of select commercial and industrial facilities, and we interviewed the operators of these facilities where necessary. All interviews and conversations were critical additions to the raw data provided and helped form the basis for the smarts grid's potential efficacy of reducing energy consumption on the island. The data we gathered from multiple sources will be combined to support the cost-benefit analysis and results.

The information presented in this report and our recommendations can inform the NESC's decisions and actions pertaining to Nantucket's future energy infrastructure and better position the Committee to actively pursue paths to achieve their goals.

Literature Review

United States Electric Grid Issue

The current United States electric grid is reaching its limit due to both the increase in demand as well as the current age of the grid. Both have been pushed to the limit since around 1982, driven by increased population and rising per capita consumption as people adopt high-powered technology at home on a daily basis. In an era of rising energy consumption, investment in the transmission lines for delivering power to the end consumers has lagged. This underinvestment strained the grid, resulting in major costly power outages, inflicting annual costs to American businesses of nearly one hundred million dollars (US Department of Energy, 2008). "Electricity distribution networks have entered a period of considerable change, driven by several interconnected factors; ageing network assets, installation of distributed generators, carbon reduction targets, regulatory incentives, and the availability of new technologies" (Wade, 2010). The higher demand for energy has prompted support for new federal energy policies to upgrade the nation's electric grid.

If the current electric grid remains unchanged, future problems will materialize on a widespread scale: higher energy prices, possibly more outages, and a decrease in power quality due to inefficiency. According to CQ Researcher, demands imposed on the electric grid's services have risen steadily but "investment" in energy transportation has only crept in comparison (Weeks, 2010). In response to the increasing alarm over this lack of attention to the electric grid, the federal government has recently invested $3.4 billion in research into smart grid technology in order to enhance the electric grid's reliability (US Department of Energy, 2008).

Smart Grid Technology

Ideally, a smart grid system actively communicates power output and input information and distributes power accordingly between power production facilities, transmission and distribution systems, homes, and appliances. It also enables consumers to make informed choices, actively participating in modifying their energy consumption rates based on the information and control options a smart grid can provide (US Department of Energy, 2009b). At its best, a smart grid anticipates and reacts to system interruptions, avoiding outages and rerouting power around disturbances in a solid grid network.

Smart grid systems are built to conserve energy and adjust supply to match demand. To do so, they must enable bidirectional flow of energy, provide a two-way communication system between the end-user and the utility, and have control capabilities (US Department of Energy, 2008). Various communication systems being explored for smart grids include 4G networks, Wi-Fi, radio, or cable (J. Edwards, personal communication, 2010). Smart grid systems differ in design but typically include periodic communication of current, phase, and frequency data to the user and to the utility (Beyea, 2010). Due to the complexity of the design of a smart grid, the infrastructure of a smart grid system is fairly extensive and multifarious. One of the most commonly referenced tools is the ‘smart meter’ (See Figure 1).

Figure 1: Smart Meter
(Raftery, 2008)

Smart meters measure the data needed and communicate with a control center. They would replace the meters found on every home, commercial, or industrial building that receives electricity (US Department of Energy, 2008). Installed on homes, smart meters offer consumers detailed reports on electricity usage and pricing options, can incentivize the consumers to reduce their peak energy consumption by rate changing or dynamic pricing options (Weeks, 2010). For example, 1,400 participants in a Washington D.C. study installed eMeters (a brand of smart meter) in their homes and were offered three pricing options. Altogether, 90% of the participants saved money on their monthly electric bills and reducing peak energy consumption (Rudra, 2010). Smart meters would also give control over meters from the utility. For example, if a user wanted its electricity shut off they could have it automatically shut off by the utility company through communications in the smart grid system instead of having to send a lineman out, saving time and money (D. Hurley, personal communication, December 3, 2010).

Smart meters provide utilities with the means of varying prices during the day to urge consumers to use electricity when it is least expensive to produce, also known as off peak-hours. This varying rate structure is detailed later in Automated Meter Systems and Rate Structures section.

Advantages

Smart grid systems alleviate many problems of the current electric grid. First, it decreases the amount of power a generation facility needs to produce because power utilities know exactly how much electricity the grid requires at any given time. Not only would this save money for consumers, it also reduces the amount of harmful air emissions from electricity generation. To accomplish this, a smart grid needs a bidirectional flow of communication between meters where energy is flowing, a control center at a substation to direct the flow of electricity to where it is needed, and the power plants creating the electricity (General Electric Company, n.d.). Secondly, a smart grid integrates renewable energy almost flawlessly into the grid by communicating how much input the renewable energy resources would add to the grid and adjusting variables in the system, such as voltage and amount of utility power, to account for them.

Annual power outages are on the rise, particularly in the United States (US Department of Energy, 2008). If one transformer fails, an entire block or neighborhood or more will be out of power. If the grid is 'intelligent', however, it could transmit information about the outage to the control center and reroute electricity around the power outage, if possible, preventing a blackout. Such a "self-healing" system, which maximizes performance and reduces unexpected failures of primary equipment through "alerts detection, diagnosis and prognosis," is known as asset optimization (General Electric Company, n.d.).

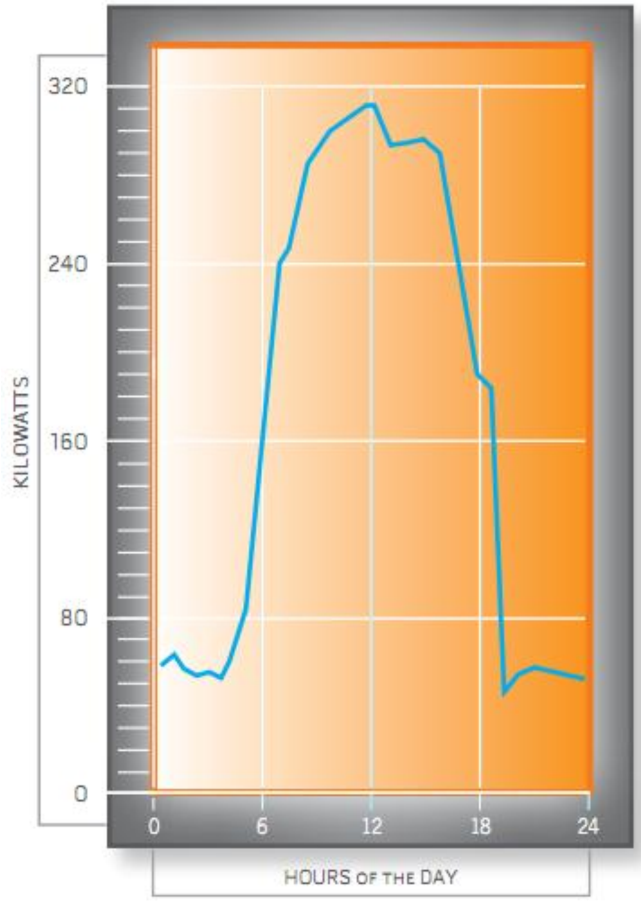

Figure 2: Typical Daily Load Profile
(US Department of Energy, 2008)

Smart grids also would reduce the load during peak energy consumption hours. The peak hours of the day are when the utility companies produce the most expensive energy (see Figure 2). This is explained by the inefficiency of bumping up generators for short periods of time. The introduction of smart meters allows consumers to monitor hourly electricity consumption and offers the possibility of raising peak hour prices due to the increase in demand for that energy and lowering off peak demand prices. Consumers would then become more aware of the energy they use at various times of the day, urging them to conserve energy at certain times and run appliances at night. The smart grid, in theory, can reduce the peak load by encouraging consumers to use less energy during peak hours, leveling the peak, and creating a more even production of energy for the power plants and decreasing the cost of electricity (Beyea, 2010).

Disadvantages

While smart grid solves many problems, it is costly to implement. Not only do utility companies need to install the systems, they also need train their own personnel or hire third parties to maintain these systems. With this, there is considerable financial risk. While payback to utilities is expected due to lowered maintenance costs, and payback to consumers is expected due to reductions in electricity use, the savings are not guaranteed (Forum's Energy Industry Partnership, 2010;Bossart, 2009). The price of electricity could actually increase with the installation of a smart grid especially if the installations were not paid for or subsidized by federal grants as they are currently being funded in today's pilot programs.

Furthermore, smart grid technologies are evolving rapidly and may become more cost effective causing many companies not to invest until the technology tested extensively. John Anderson, the president and CEO of the Electricity Consumers Resource Council, raises several important issues regarding the costs and benefits of smart grid systems. Anderson notes that developing a smart grid for the US may cost roughly $1 trillion, but it remains unclear, who will pay and what the energy and economic savings will ultimately be. Most industrial consumers are most concerned about smart grid costs. Anderson implies if a smart grid system is installed that includes a pricing plan; the cost of electricity will go up, especially during peak hours. "If a smart grid is to be successful," Anderson stresses, "consumers must be convinced that the net benefits outweigh the costs and those must be benefits that consumers truly want and understand" (Anderson, 2010).

Automated Meter Systems and Rate Structures

Most markets in the world today are based fundamentally on supply and demand: as demand rises, so will supply until producers and consumers reach equilibrium. If supply is limited but demand is high, equilibration comes about through a rise in costs; if supply is ample but demand is weak, costs fall. Such equilibration in the electric grid is not fostered under the rate structures most utilities now have in place. Rates are invariable throughout the day and may change only once a month. Thus, the price for those demanding electricity from the grid is flat, even though supply is more limited at certain hours than others.

Yet the cost of producing electric varies greatly, depending on time of day and the cost of particular fuel used in generation. Consumers who do not use electricity during peak demand hours still pay the average electric fee, which factors in the utilities' high supply costs necessitated to meet peak consumption.

Not only do spikes in energy increase cost of electricity, but they also are the cause of many brown outs and black outs when the grid cannot produce the capacity needed. Unlike a supermarket where a particular product may be "temporarily out of stock," when electricity is momentarily out of stock, the instantaneous result is a brownout or blackout. One strategy for avoidance is to have idle excess generating capacity available, which can be activated instantaneously, but is very expensive. Another strategy is to prepare consumers to limit demand at certain peak times. To meet the goal of reducing demand at peak hours, consumers are offered a monetary incentive.

A different rate structure has been developed, which depends on the time of day the consumer uses electric. Under time-of-use (TOU) rates, users pay higher prices during high demand and enjoy lower prices during lower demand. The TOU rate structure is currently offered only to large commercial users, which consume vast amounts of electric in comparison to the average household. The TOU rate structure is intended to discourage energy use during high demand hours and encourage use at other non-peak use times. Electricity is unique in that supply must *always* meet demand, moment by moment. Demand exceeds supply, and electric lines, which carry power to everyone, overload with power and stop performing. The following table includes rates as an example of a TOU rate structure.

Rate Period	SUMMER: July and August	SWING: June and September	WINTER: October through May
Weekday Off-Peak	10 pm to Noon (9.05¢)	10 pm to Noon (8.32¢)	10 pm to 6 am (7.61¢)
Weekday On-Peak	Noon to 5 pm (17.79¢)	Noon to 5 pm (12.98¢)	6 am to 5 pm (9.74¢)
Weekday Super-Peak	5 pm to 8 pm (23.02¢)	5 pm to 8 pm (15.64¢)	5 pm to 8 pm (10.73¢)
Weekday On-Peak	8 pm to 10 pm (17.79¢)	8 pm to 10 pm (12.98¢)	8 pm to 10 pm (9.74¢)
Weekend and Holiday Off-Peak	10 pm to Noon (9.05¢)	10 pm to Noon (8.32¢)	10 pm to 6 am (7.61¢)
Weekend and Holiday On-Peak	Noon to 10 pm (17.79¢)	Noon to 10 pm (12.98¢)	6 am to 10 pm (9.74¢)

Table 1: PowerChoice TOU Rate Structure
(Lutzenhiser, 2009)

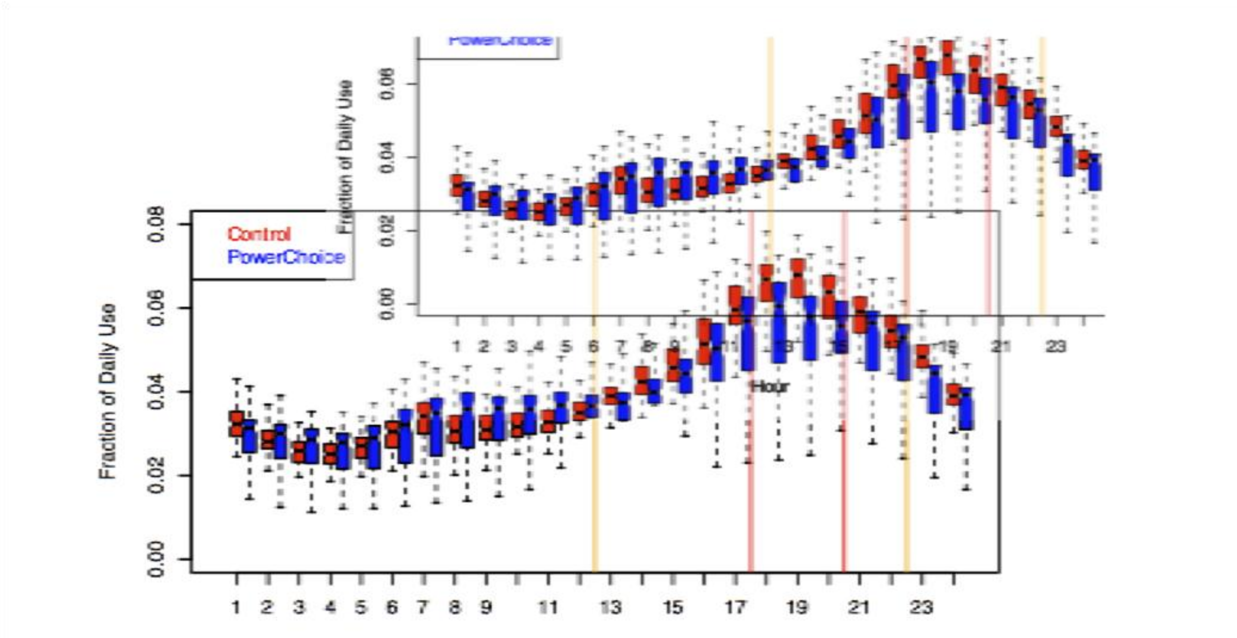

Figure 3: Normalized Load Shapes for Control Group and PowerChoice customers: Summer Weekday
(Lutzenhiser, 2009)

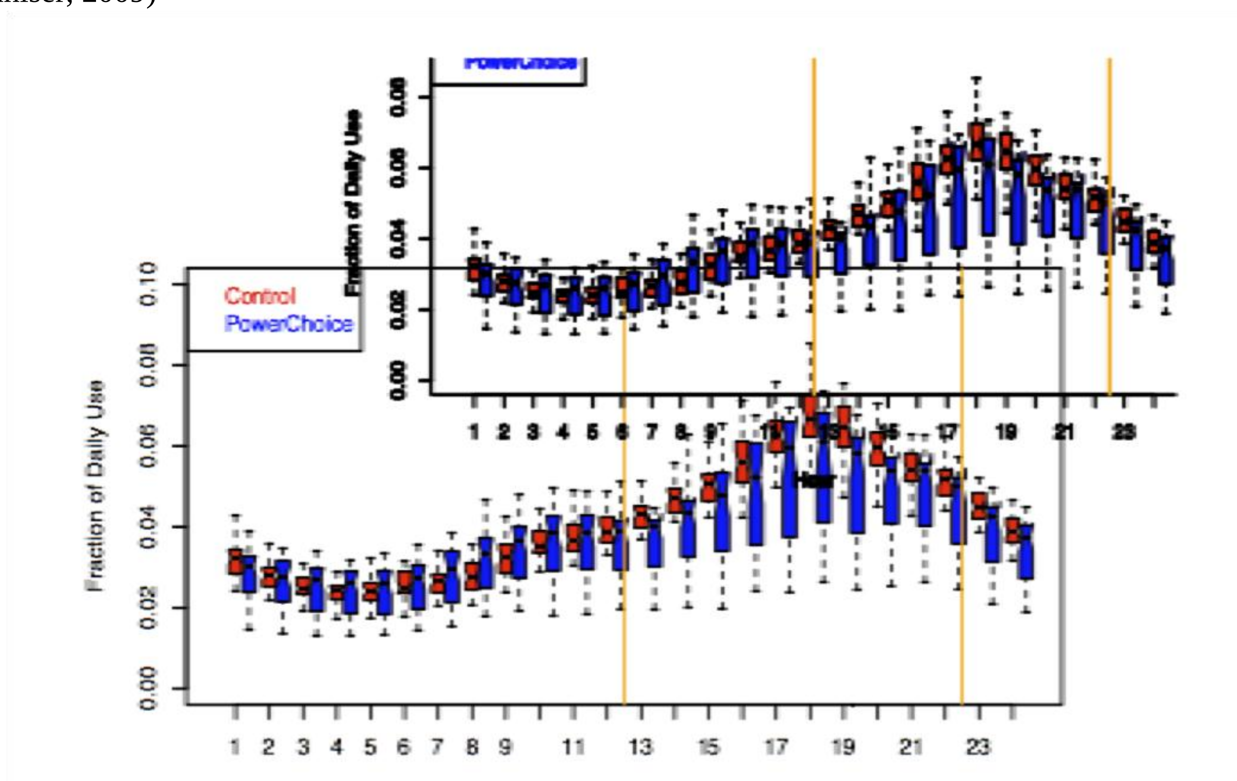

Figure 4: Normalized Load Shapes for Control Group and PowerChoice customers: Summer Weekend
(Lutzenhiser, 2009)

TOU rates have proven in smart grid pilots have been shown to reduce the electricity peak as shown in Figures 3 and 4 above. The red bars represent the control groups that did not have a TOU rate, and the blue represents the group that did have a TOU rate. As you can see, the time of use rate reduced the peak load, more so in the weekdays than the weekends.

Rate	Peak Time Pricing		Peak Time Rebate		8-Hour time of Use	
Customers	Rate Alone	Rate w/Controlling Technology	Rate Alone	Rate w/Controlling Technology	Rate Alone	Rate w/Controlling Technology
Residential	-16.1%	-23.3%	-10.9%	-17.8%	- 3.1%	
Business	-2.8%	-7.2%	0.0%	-4.1%	0.0%	

Table 2: Rate Structure Peak Reduction Comparison
(Miller, 2010)

Research shows that consumers will limit energy use in response to higher electric prices during typically high demand hours under a TOU rate structure (Lutzenhiser, 2009). As seen above in Table 6, some TOU rates work better than others at decreasing the overall electricity power peak consumption. When a peak time pricing TOU rate is applied in a residential area, the power peak reduction is approximately16.1%. With rate controlling technology such as smart appliances and thermostats, peak power reductions reach 23.3%. Implementing TOU rates, however, is possible only if the electric grid can automatically record consumption for small time intervals[4]. The technology behind tracking consumption is termed Automatic Meter Reading (AMI). AMI systems are typically implemented in areas that plan on also changing their rate to TOU or dynamic structures (Hughes, 2008). Dynamic pricing structures are based on daily

[4] Time intervals between meter reads vary, but optimally they are in increments of 15 minutes or less, the more frequent the meter reads the more the consumer can recognize behavior patterns and change (Silver Springs Networks, 2010a).

conditions[5] rather than typical patterns (TOU); the utility predicts high demand days and informs the consumer population of the rate change based on forecasted demand (Hornby, 2009). Coupling TOU or dynamic rates with the infrastructure of an AMI system (which includes more advanced meters) can reduce peak demand (US Department of Energy, 2009b).

Activity	**Percentage Reporting a Change in Usage**
Clothes Dryer – *changed timing or used less*	91%
Dishwasher – *changed timing or used less*	68%
Central Air Conditioner – *changed hours of use, used fewer hours, or increased set-point*	63%
Installed CFLs	62%
Cooking – *changed timing, method, or foods prepared*	28%
Pool Pump – *timing or duration*	20% of all, 80% of pool owners

Table 3: Most Common Shifting and Conservation Actions in Response to PowerChoice (Lutzenhiser, 2009)

Most consumers are not well informed about how they have an effect on the electric grid. One goal of a smart grid is to provide consumers with information about monitoring usage to use less electricity during peak hours of the day. Information distributed to the consumer through up-to-date Internet portals about their hourly consumption induces higher reduction responses (Federal Energy Regulatory Commission, 2009). Consumers were more likely to use energy during off peak hours for some actions than others, as detailed in Table 3 above. "Many of the other benefits of deploying an AMI also increase when the percentage of customers served increases" (Hughes, 2008, p.31). According to the US department of Energy the majority of the benefits that can and will be experienced from rate structure changes as well as AMI systems will be in the residential sector, which has the potential to affect 43.6% the peaks with full implementation (US Department of Energy, 2009b, p.37).

Smart Appliances

‘Smart’ appliances, such as thermostats, will contribute to the future of smart grid systems where the thermostat or appliance, including but not limited to dishwashers or laundry machines, could be set on timers to run when electricity is at its lowest peak. Synchrophasors are similar to smart meters in that they provide measurements of electricity and transmit information in real time about entire grids to a control hub (Schweitzer Engineering Laboratories, n.d.). With

[5] Dynamic rates are rarely instituted (typically only 15 days annually) but include significantly higher rates.

the recently developed capability to communicate information about power usage instantly, comes the problem with distributing those data correctly. 'Smart' automated substations fill the gap because they communicate information from smart meters to other automated substations and can respond to situational changes (Pritchard, 1998). A 'smart' transformer is another device designed to communicate with a control station. They are designed to detect gasses emitted when the transformer breaks down or wears out so that the power company can reroute the electricity around that transformer and replace the transformer as soon as possible, preventing blackouts (Smart Sensors and Integrated Microsystems, n.d.). The aforementioned devices used in combination or selectively form the basics of the smart grid infrastructure.

Smart Grid Funding

Smart grid infrastructure has a huge initial investment cost in order to install and purchase the hardware and software. The initial investments cost $220 to $600 to every smart meter installed (Hornby, 2009). If no grants were received to cover the cost of the smart grid the utility would pay the initial costs and charge the residents a fee for infrastructure costs. However, recent federal interests have centered on providing grants for smart grid technology research and pilot studies.

Congress first brought smart grids to the forefront of the government's initiatives in adopting the Energy Independence and Security Act of 2007, which highlighted smart grid as a tool for modernizing the current US electric grid by increasing grid security and the efficacy of national power consumption (Energy Independence and Security Act of 2007, 2007). On January 6th, 2009, the Obama Administration 2009 stimulus invested $4.5 billion to "modernize the electric grid, to include demand responsive equipment, enhance security and reliability of the energy infrastructure, energy storage research, development, demonstration and deployment, and facilitate recovery from disruptions to the energy supply" (American Recovery and Reinvestment Act of 2009, 2009). According to a White House press release, $3.4 billion of the stimulus package will go directly to encouraging smart grid pilots and research. Roughly $2 billion will focus on integrating and crosscutting across different "smart" components of a smart grid. This will fund projects focused on installing smart meters, smart thermostats, smart appliances, syncrophasors, automated substations, plug-in hybrid electric vehicles, renewable energy sources, etc. (The White House, 2009). One billion dollars of the investments fund consumer awareness encouraging consumers to save energy and cut utility bills. This will invest in infrastructure to "expand access to smart meters and customer systems so that consumers will be able to access dynamic pricing information," and to save money by setting smart appliances to run in off-peak hours. The Recovery and Reinvestment Act of 2009 also includes $400 million to make electricity distribution and transmission more efficient to reduce the amount of energy that is wasted between where it is produced to where it is used. The smallest section of the act includes $25 million to increase the manufacturing industry of smart meters, smart appliances, syncrophasors, smart transformers, etc. in the United States (The White House, 2009).

Other organizations play a large part in regulating the market and policy drivers. For example, the National Energy Technology Laboratory (NETL), a U.S. Department of Energy laboratory, has helped catalyze the transition to smart grids by creating the "Smart Grid Implementation Strategy" team. This team focuses on Smart Grid evaluation and implementation planning, case development at a various levels, engineering analyses to strengthen understanding of smart grid deployments, and integration into smart grid organizations to optimize overall effectiveness of smart grids (National Energy Technology Laboratory, 2010).

Smart Grid Security

A unified smart grid system poses concerns for security breaches within cyberspace. If someone were to hack the cyber system of the advanced metering infrastructure (AMI), depending on the system, that person could completely disconnect power to a household, or turn off specific appliances in a house. By hacking into the entire system, someone could create an entire blackout of the area the smart grid connects. Furthermore, viruses or malware released in the system might disrupt power to thousands of people. One issue with smart grids is that the meters are outside and hence accessible (Sorebo & Echols, 2010). According to the article *Protecting Your Smart Grid* by Michael Echols and Gib Sorebo, "the best way for utilities to provide assurance their cyber security risk is being managed is to require their smart elements to adhere to a standard set of security principles" (Sorebo & Echols, 2010).

Although physical assets connecting the grid may be vulnerable, distributed generation, which is a proponent of smart grid, could temper vulnerability on the generation side. Prior to small-scale power production, the grid supplied power through a few main power sources—ideally suited to intentional disruption of power on a large scale. If only one of these main power sources were left vulnerable and attacked, a large proportion of the grid would fail, costing consumers. In this way incorporating many different sources such as would be more reliable.

Also, a smart grid would increase reliability by its ability to communicate blackouts or breaks in the grid system and reroute electricity around failures in the grid.

Smart Grid Standards and Information Portals

The resident expert in the US on smart grid standards is the National Institute of Science and Technology (NIST). Outlined below are the 5 most critical standards of 75, which the NIST has developed along with other regulatory institutions such as CENELEC.

> The standards and their functions are:
> IEC 61970 and IEC 61968: Providing a Common Information Model (CIM) necessary for exchanges of data between devices and networks, primarily in the transmission (IEC 61970) and distribution (IEC 61968) domains.
> IEC 61850: Facilitating substation automation and communication as well as interoperability through a common data format.
> IEC 60870-6: Facilitating exchanges of information between control centers.
> IEC 62351: Addressing the cyber security of the communication protocols defined by the preceding IEC standards.
>
> [Bello, 2010]

The five standards refer to the exchange of information. The most widely used portal for the exchange of information is the Internet, which can handle numerous forms of communication applications (Silver Springs Networks, 2010b). Some of the carriers for internet protocol (IP) are "WiFi, Wi-max, Zigbee, Z-wave, DS2, Homeplug, [and] a variety of cellular standards" (Silver Spring Networks, 2010b, p.3). All of these are viable options since the use of one does not preclude the option of integration with another.

Some of the suggested methods for contacting customers directly with pertinent consumption information through IP are in house equipment (e.g. programmable thermostat displays), websites, telephone, email, or bills (Silver Spring Networks, 2010b, p.3).

Through these portals, information can be exchanged reliably and consistently (either on demand or on a scheduled basis), which has proven to be instrumental in making AMI systems like a smart grid cost effective (Hughes, 2008). The information allows the end consumer to choose to take advantage of changes in price, either through time of day rates or incentives offered by the utility, and thereby alter usage. The use of this type of software for information distribution should be cautioned though, due to the critical maintenance necessary to keep software up to date and therefore the additional costs are represented in software updates. The upgrades that new software brings also may generate more cost savings, but the system must have the ability to update remotely for it to be cost effective (Hughes, 2008). Since this information will be funneled through the Internet, certain security standards should also be met and kept up-to-date with all accessing software systems also in compliance with the standards.

Pilot Projects

In 2010, following the US Department of Energy's clarified definition of Smart Grids, approximately 90 pilot projects were under way worldwide (Forum's Energy Industry Partnership, 2010). Major countries like Japan, the United States, the European Union (E.U.) and China should all have different agendas for upgrading their electric grids based on current issues within each country, according to Hironori Nakanishi, a representative of Japan at recent smart grid conference in Maryland. This individualized approach to smart grid is also backed by the World Economic Forum (WEF), which recognizes that America must solve issues of grid reliability, load reduction, renewable integration and customer relations (Forum's Energy Industry Partnership, 2010). Nakanishi identifies a few overwhelming concerns, such as weak transmission infrastructure, old power plants, lack of information about electricity supply, and young businesses delving into demand side communication systems. Nakanishi states that unlike America, Japan and the E.U. have more reliable grids. The Japanese and Europeans have also made more efforts to integrate renewable energy to the grid. The countries are currently developing partnerships to benefit from shared knowledge and cost diffusion. Okinawa, Japan is partnering with Hawaii to study smart grids on the similar islands. The E.U. is running studies with globally known American companies[6] in the United Kingdom (UK), Sweden, Finland, Amsterdam, Denmark and Malta. America may be struggling with more outages but has recognized its need to progress forward in knowledge as well as infrastructure. (Nakanishi, 2010)

Smart Grids are still in the piloting phase of a new technology but there have been versions of "semi-smart" grids since the 1990's. Southern California Edison has been running pilot smart metering of end users in an attempt to create an advanced metering infrastructure (AMI) (Johnson, 2010). As an example of the current pilot programs, S & C Electric Company in California began work on the IntelliTEAM Automatic Restoration System in 1997, which was meant to reroute electricity around breaks in power lines (S&C Electric Company, 2010). One of the principal characteristics of a smart grid that NETL has identified is the ability to such as this grid "self heal" breaks in power lines (National Energy Technology Laboratory, 2007). S & C inadvertently began delving into smart grid technology the moment they started their

[6] Companies with projects in EU: GE, IBM, Cisco, Accenture

IntelliTEAM project (S&C Electric Company, 2010). Many of the pilots conducted in the last decade are similar in situation, which means they incorporated some facet of the smart grid concept.

As smart grid technology is more and more publicized, there is a common conception of what smart grids comprise of and what they are intended to achieve. More pilots are appearing that incorporate all of the NETL defined characteristics (National Energy Technology Laboratory, 2007). National Grid, a power utility in Massachusetts, plans on incorporating a pilot study in Worcester, Massachusetts. National Grid has applied and received a grant from the U.S. government to install 15,000 smart meters in the Worcester area (National Grid, 2009a).

Austin Energy was one of the first true smart grid systems in the United States, beginning in 2003 and is one of the longest studied smart grid systems (Austin Energy, 2010), and also one of the largest, covering 1 million consumers and 43,000 businesses (Austin Energy, n.d.). Austin began developing its smart grid by replacing a third of its manual meters with smart meters. It now has approximately 500,000 smart meters, smart thermostats and sensors installed across its service area (Austin Energy, n.d.; Austin Energy, 2010). According to Mary Cronin, a professor at Boston College, Austin Energy is now creating newer smart grid programs that are creating smart grid ‘ecosystems’ to create new business models such as a $10.4 million Department of Energy funded program called the Pecan Street Project (Cronin, 2009). This project is evaluating an open platform energy Internet on a very small section of the energy grid system; a microgrid (Cronin, 2009). The project will include more information on energy storage installation and testing, smart grid water and irrigation systems, smart appliances and electric vehicles and will also include some solar power energy integration.

Another pilot program, SmartGridCity, sponsored by Xcel, created another grid system in Boulder, Colorado (Xcel Energy, n.d.b). The first phase of the project began in 2008 so it is still relatively new. Recently they have implemented a pilot run of a pricing challenge offering customers different pricing options, thereby enabling them to take an active role in reducing energy (Xcel Energy, n.d.b). Also they plan on doing a combined electric vehicle study with Toyota on the Toyota Prius Hybrid (not yet under way).

These pilot programs only just begin to describe the different types of smart grid systems that exist and what smart grids could provide. Detailed reports have not come out on many pilot programs and little is known about the results of the pilot programs.

Smart grids are a very flexible technology for accomplishing many different objectives. Often, when smart grids are brought into the picture, so is renewable energy. This is because smart grids are able to incorporate the energy produced into the grid system and distribute it to exactly where it is needed, termed a distributed system.

Nantucket Island Electricity Profile

Supplying electricity is no easy task given Nantucket's location 26 miles away from the nearest substation on the southern shore of Cape Cod. Nantucket's current energy provider, National Grid, supplies the Island's electricity through two submarine cables buried eight feet below the seabed (Nantucket Electric, 2010). The first 35 MW cable (installed in 1996) made it possible to shut down the Electro Motive Diesel (EMD) plant located in Nantucket's Candle Street historic area, which supplied the island with around 20 MW of electricity (Business Wire, 1996). According to many Nantucket residents, the EMD plant could not produce enough electricity in peak times, causing frequent blackouts and brownouts across the island. Before the first cable was installed, Wannacomet Water Company occasionally ran their backup generators to reduce the high electricity demand (R. Gardner, personal communication, November 5, 2010). The cable was successful in improving the electric supply reliability and rate stability.

Given Nantucket's vacation appeal, the Island's year-round and seasonal population continued to expand after the first cable was installed, and electricity usage grew rapidly as well (Nantucket Electric, 2010). To keep up with demand, a second 35 MW cable was installed in 2005 and was in service on April 16, 2006 (see Figure 5).

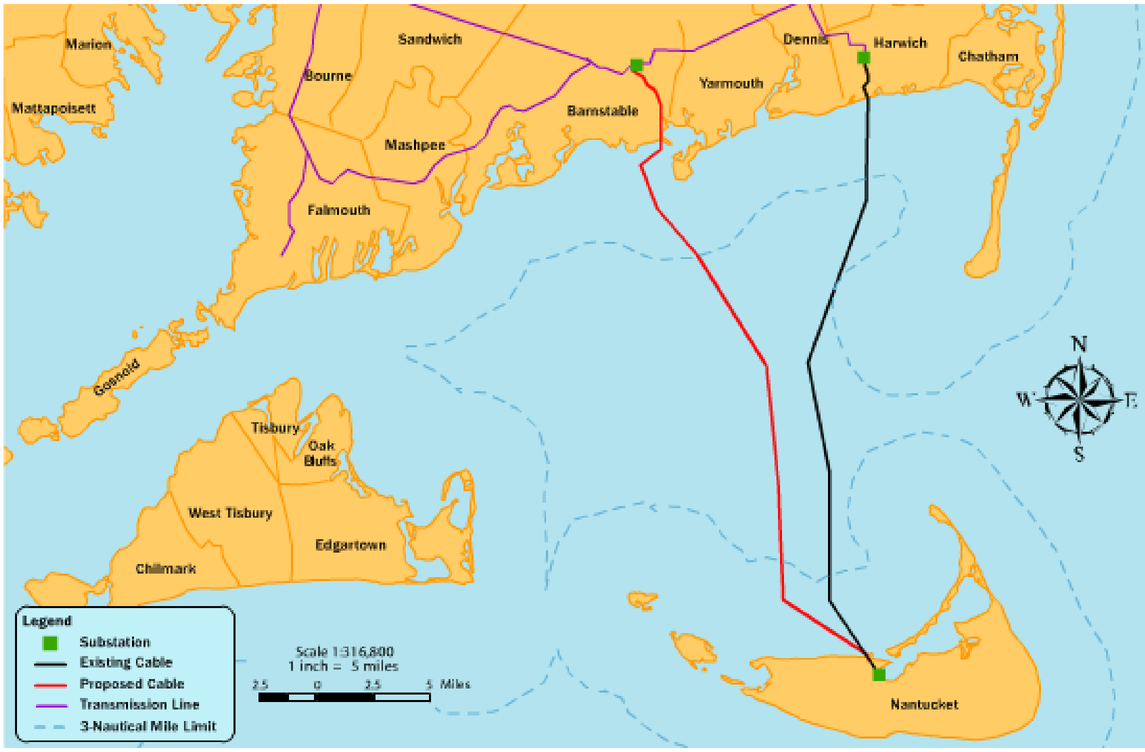

Figure 5: Proposed Second 35 MW Cable to Nantucket Map
(National Grid, 2010c)

Conservation tactics were investigated by National Grid before installing a second cable, but due to having so few large commercial users on the island, it would not significantly reduce the amount of energy the island would have needed (Nantucket Electric, 2010). The second cable was in service on April 16, 2006. With the installation of infrastructure such as underwater sea cables comes a price. According to Trish Fairwater, the project cost was $41 million. In order to pay off the installation of these cables, National Grid added a surcharge on the delivery prices. From June to September, Nantucket residents pay 2.958 cents/kWh and from October to May they pay 1.834 cents/kWh for the cable surcharge (Nantucket Energy Study Committee, 2009).

The graph below displays the summary of rates based on variable rates and clearly shows a spike in electricity rates when second cable was installed between 2005 and 2006 (see Figure 6).

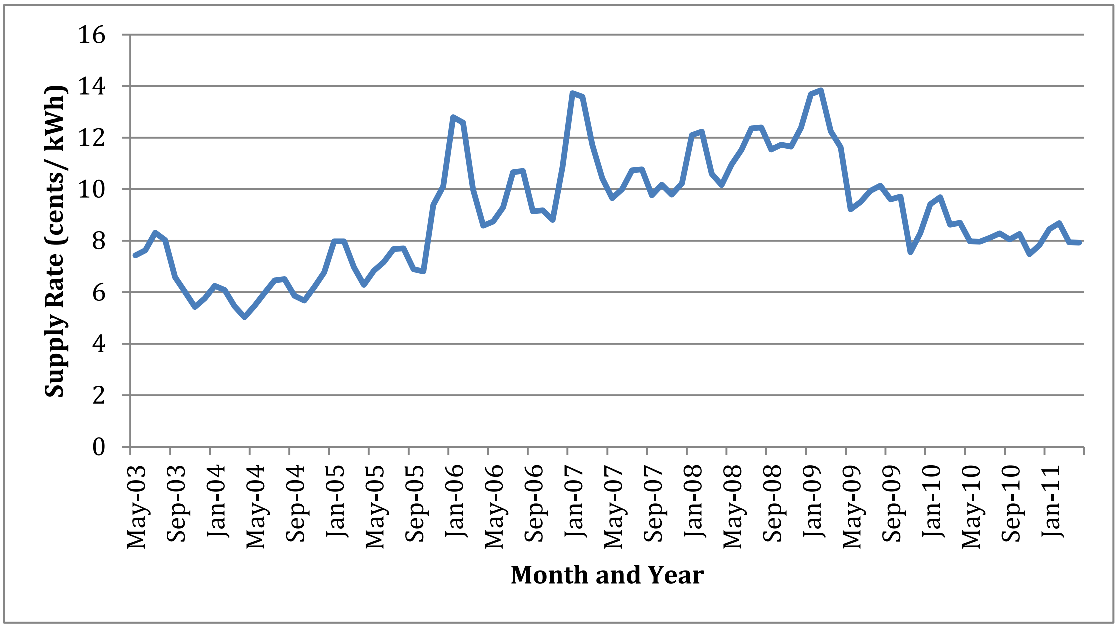

Figure 6: Nantucket National Grid Electricity Supply Rates
(National Grid, 2010a)

In comparison with the rest of the country, Nantucket has a much higher electricity rate. In August 2009, the average residential price of electricity in the United States was 12.00 cents per kWh (US Department of Energy, 2010a). The price of electricity per kWh in Massachusetts during the same time period was much higher, averaging at 16.03 cents due to a lack of natural resources for inexpensive energy production (US Department of Energy, 2010a). Nantucket had the highest price out these three at the price of 18.4 cents per kWh because of its location (National Grid, 2010e; National Grid, 2010a). This difference between the state of Massachusetts and Nantucket amounts to a 15% increase in energy prices.

The current utility provider, National Grid, divides its consumers into various sectors. The residential sectors include the basic residential rate (R-1), low-income rate (R-2), and the optional residential time-of-use rate (R-4) (National Grid, 2009b). The R-1 rate is available to all domestic residential users, and the R-2 rate is a reduced rate if users earn meet certain criteria from the government. The R-4 rate is for the larger residential energy consumers with usage that exceeds 2,500 kilowatt hours (kWh) per month for a twelve month period (National Grid 2009b).

The commercial and industrial facilities on the island are the small commercial and industrial service rate (G-1), general service commercial and industrial demand rate (G-2), and the general service commercial and industrial time-of-use rate (G-3) (National Grid, 2009b). The G-1 rate are typically the small commercial and industrial users who consume less than

10,000 kWh per month or have less than 200 kilowatts (kW) per month in demand. The G-2 rate represents the medium commercial and industrial users on the island who consume more than 10,000 kWh per month and not exceed a demand of 200 kW per month. The final G-3 rate represents the few large commercial and industrial users who have an average monthly demand of 200 kW or greater for three sequential months (National Grid, 2009b). There are separate rates for streetlights and they are company-owned street lighting service rate (S-1), customer-owned street lighting service rate (S-5), and the company-owned sodium conversion lighting service rate (S-20) (National Grid, 2009b).

The delivery service rates are dependent upon the sector the user is classified as, but there also exists the supply rate. If the end user doesn't select a competitive supplier, National Grid provides basic supply service for the customers (National Grid, 2009b).

Conservation Efforts

The potential benefits of using a smart grid to leverage greater success in conserving electricity are immense, and required significant research. Research also delved into the classifying of various conservation methods as either simple conservation techniques or more intensive conservation techniques. Conservation is generally recognized as a process by which consumers reduce the use of a scare resource; in this case electricity and can bring the supply and demand of the resource back into balance. There is a key difference between conservation methods and a smart grid though, in that conservation of electricity as a standalone technique cannot alter the peaks of use throughout a day or season. Conservation has the ability to reduce the overall amount of electricity used, thereby cutting base load electricity.

Overall electric conservation can be achieved through many avenues, some of which include: upgrades to small items in homes, major facilities upgrades, and overall lifestyle changes. Small upgrades that can be installed into homes with very little trouble are programmable thermostats, compact fluorescent lamps, and converting all appliances to Energy Star rated appliances. The significant benefits of small upgrades make them very advisable considering the relative low cost of the installation and operation of all devices (Loder, 2009).

The available major upgrades to building efficiency are much more costly than small upgrades, but in return, provide your facility with an exponentially improved electricity savings. The options studied in this report detail improvements such as the installation of a geothermal heat pump, HVAC system improvements, and new windows with improved coatings. While some of these upgrades could be cost-prohibitive to some users, the payback periods do not make them unreasonable (US Department of Energy, 2009a).

In Table 4 below, the most highly recommended conservation methods and the potential impact that could be felt by each home that implements the technique. Each of these methods has been suggested by at least two sources, and each provided examples of successful implementation. The information below has a strong potential to bring about change wherever it is implemented, and can supplement other technologies and methods of reducing overall electric use and instantaneous electricity peaks.

Conservation Method	**Impact**
Programmable Thermostats	8% electricity cost reduction per year, per home. The payback on the average device is only 3 months.
Compact Fluorescent Lamps (CFLs)	7% household electricity use reduction. The payback averages only one month for the average bulb and use pattern.
Unplugging	7.5% reduction in household electricity use, the payback period is instantaneous for unplugging since there are no associated costs.
Energy Star Appliances	Can reduce electric use of appliances by 50%, and the payback periods vary greatly between devices.
HVAC Inspection	20% reduction in building energy use due to improved efficiency.
Geothermal Heat Pumps	30% electricity cost reduction, longer payback period due to high cost of installation.

Table 4: Conservation Methods and the Associated Savings
(Department of Energy, 2005; Energy Star, 2009; Ghanta, 2010; US Department of Energy, 2009a; US Department of Energy 2010a; Loder, 2009)

Renewable Energy

Recently, there has been an increased investment in renewable energy, such as wind and solar energy. The term “renewable” means that energy is produced from resources that are endless. Renewable energy is an alternate way to offset energy demand, with the additional benefit that there are no harmful air emissions from the production of renewable energy. However, the incentives for renewable energy generation are not just environmental, but also cost related in the U.S. (Heal, 2009). According to a cost analysis of generating electricity in 2010, “coal, gas, nuclear, […] hydro and wind are now fairly competitive generation technologies for base load power generation" (Khatib, 2010). This is due to factoring in carbon pricing and trading, which may rise to $30 per ton, increasing coal production prices by almost 100% (Heal, 2009; Khatib, 2010). Due to this competitiveness in energy costs, there is an active search for more renewable energy sources, such as wind energy, solar energy, and tidal power.

Wind

'Wind energy' refers to energy derived from the renewable resource of wind. Much like a windmill uses the wind's energy for mechanical power, a wind turbine converts the wind's energy to electricity. However, the inconsistency of wind energy presents limitations. According to Swearingen (2010), a major issue is that wind energy does not supply a *constant* source of power to the transmission grid. The supply of moving air is seemingly infinite, but local weather conditions are variable. Swearingen suggests that multiple wind power-generating installations could be created to provide the transmission grid with enough energy to meet the demand, just in case one of the installations were to fail or the weather conditions are unfavorable. Wind and other grid connected distributed generation has increased 134 % over three years but it only represents 1.4 percent of grid capacity. It also only represents 1.6 percent of the summer peak and 2.0 percent of the winter peak. (US Department of Energy, 2009b, p. 39)

Wind energy could offset much of the demand on current grid systems. For this to happen, utilities will need to upgrade their facilities as well as work with the renewable energy facilities (Swearingen, 2010). In addition, family-owned Bartlett's Farm installed a 250 kW wind turbine that came on line April 22, 2009 (Nantucket Energy Study Committee, 2009). This two-blade windmill produces a range of energy based on average wind speeds per month as shown in Figure 7 below.

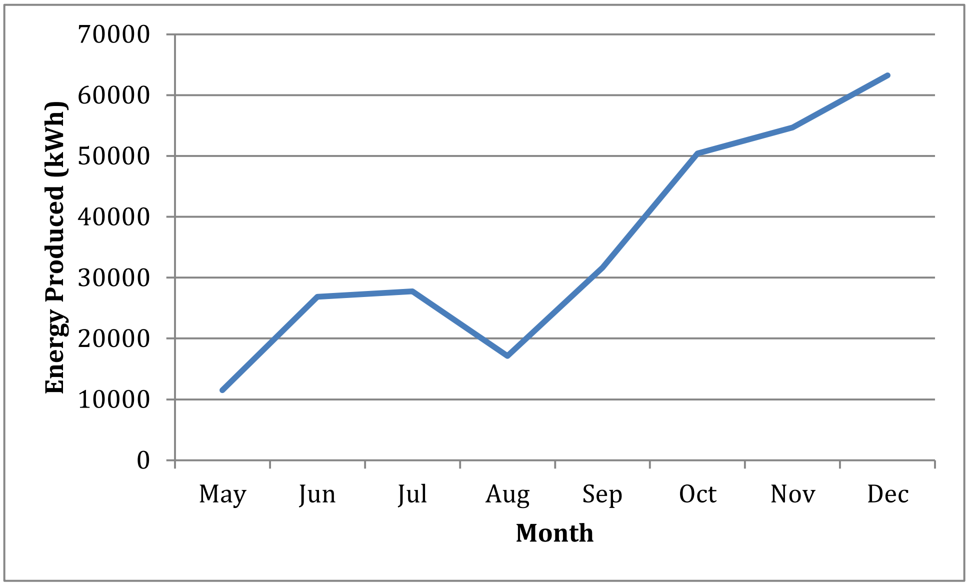

Figure 7: Monthly Energy Produced by Bartlett's 250 kW Wind Turbine
(Nantucket Energy Study Committee, 2009)

Mixed reviews accompanied the installation of the Bartlett windmill, because a 20 foot-plus section of one blade broke off only nine months after it was up and running. According to an article by Peter B. Brace, the blade's specifications should have been able to withstand the winds. Bartlett, the owner of the farm, was reticent to speak about what went wrong with the nine-month-old turbine. He did say that he would like to get the turbine back up and running as soon as possible (Brace, 2010). This caused many concerns around the town about the installation of wind turbines and the risks associated with wind energy including a blade falling off, or ice shards being thrown from the turbine (Anne Kuszpa, personal communication, November 4, 2010).

These worries have been a strong opponent in the installation of a relatively small turbine on the Nantucket High School property. Even after facing criticism, the turbine was erected early October 2010. This 100 kW turbine is located right behind the baseball backstop, between the baseball field and the football field next to the high school. Estimates have calculated that to generate over 10% of the high school's electricity (PR Newswire, 2010). Alteris Renewables assisted in the planning and implementing of the project, and projected that 192,000 kWh would be produced annually yielding significant savings on energy for the school (Alteris Renewables, 2010). It also estimated a financial commitment of $450,000, which was contingent on $125,000 of grant money from the Massachusetts Clean Energy Center.

Figure 8: Proposed Area for the 1.5 Megawatt Wind Turbine at the Madaket Landfill

The Town of Nantucket is not only looking toward the high school for wind energy but envisions installing a 1.5 MW wind turbine at the Madaket Landfill. As you can see in Figure 8, the turbine would be located away from most buildings or high traffic areas that a blade or ice shard could hit. A typical 1.5 MW wind turbine produces enough electricity to power about 500 standard homes (US Department of Energy, 2010c). The cost for installing a GE 1.5sle turbine includes the cost of the wind turbine, transportation and building infrastructure costs, development and project management costs, balances of plant costs, interconnection costs, and construction contingency plans. The final total a GE 1.5sle model wind turbine installation is about $4,945,000 or $3,297 per kW, which is quite expensive for a town to afford on its own (Black & Veatch, 2010).

The town is pushing to get the proposal through early to gain grant money toward the project, and install the turbine as quickly as possible. It has also been suggested that the town take advantage of private investors that could invest in the turbine up front. Much more planning must be done before final costs can be estimated and an investor could approve a proposal. Such planning includes how to import a crane to the island that has the capacity to lift the necessary components of a large-scale wind turbine. While the Madaket wind turbine may be installed, it is still in the drafting process and has multiple other proposals such as perhaps building three 660 kW turbines instead of one 1.5 MW to save on importation costs. It also faces many opponents in the upcoming years such as bird enthusiasts and wind turbine adversaries (W. Willauer, personal communication, November 12, 2010).

Solar

Another form of renewable energy is through a solar photovoltaic farm. Solar photovoltaic farms are currently more expensive than the current wind technology. However, the installation cost of large-scale photovoltaic cells is very high compared to other forms of energy. In order to subsidize initial installation costs of solar photovoltaic technology and make it cost competitive to other sources of energy, the government sets forth policies to subsidize initial costs through grants and tax credits. (Shum & Watanabe, 2009)

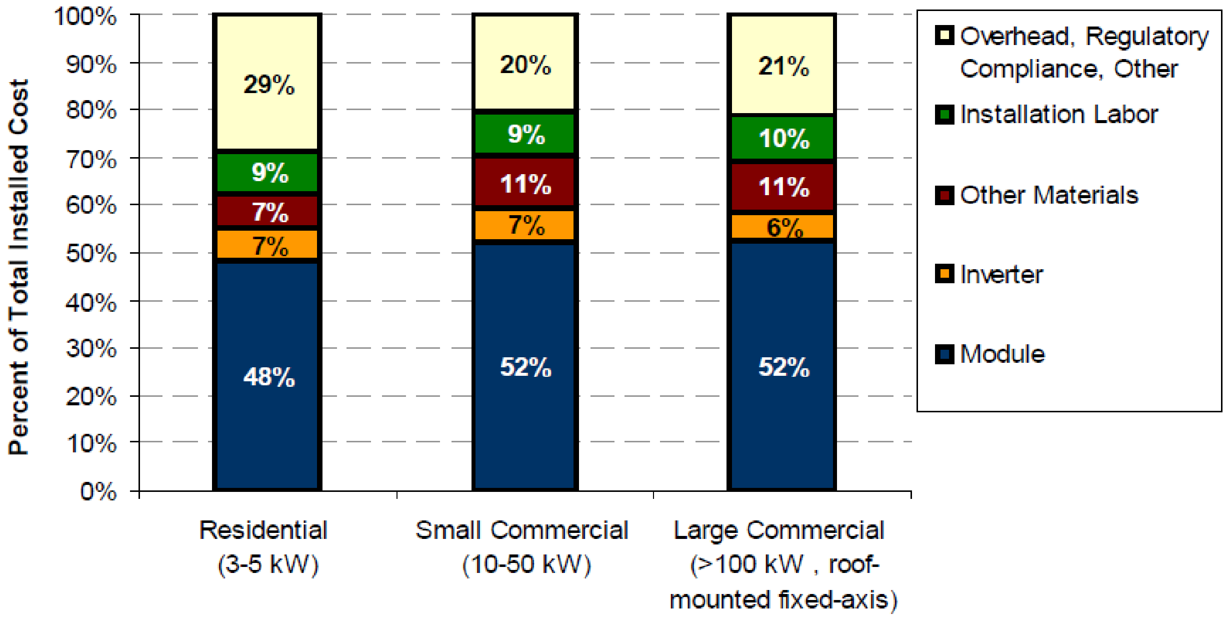

Figure 9: PV Installer Data on Component Costs
(Price, 2008)

The various costs to installing a photovoltaic solar farm include any overhead and regulatory compliance costs, labor, the power inverter, the module itself, and other materials (see Figure 9). If a price of $18 million is assumed for a photovoltaic solar array, overhead and regulatory compliance costs are about 21% or $3.8 million, and represent the costs for running the installation plus any costs associated in conforming to government requirements such as legislation or regulation. The labor cost to install the entire photovoltaic solar farm is about 10% or $1.8 million. The cost for a power inverter is about 6% or $1.1 million, and the inverter is what converts the direct current (DC) energy produced from the photovoltaic cells to the alternating current (AC) that is carried in high voltage lines to transformers. The largest price of the installation is the module itself, which is about 52% or $9.4 million. Any additional materials required to complete the installation of the farm is about 11% or $3.2 million (Price, 2008). The total price of $18 million is an estimate, but as solar photovoltaic cells become more marketable the price decreases (Price, 2008; Commonwealth of Massachusetts, 2010).

Four 2MW solar farm locations have been proposed for solar generation on Nantucket at three large energy consumers on the island. These proposed solar plants have been proposed for the wastewater facility on the island, Nantucket Memorial Airport, and two locations owned by the Wannacomet Water Company (See Appendix 14: GIS Maps of Proposed Photovoltaic Solar Farms).

The Nantucket Energy Study Committee has made implementing these alternative energy projects a top priority in order to comply with the Green Community Act in Massachusetts. This act encourages companies to incorporate renewable energy by requiring utilities to buy back a certain amount of excess power to incorporate it into the grid, called a power purchase agreement. The power purchase agreements are limited so the town must build the solar panels quickly to be considered. Another benefit to the town would be gaining Solar Renewable Energy Credits (SREC). These are a few of the ways that the town of Nantucket will be able to afford these solar farms (Patterson, 2010d).

Microgrids

Microgrids are a step that could be taken to incorporate renewable energy sources into the island. A microgrid is a smaller self-contained part of the larger electricity network that incorporates small locally generated power systems into the interconnected electrical grid (Ricketts, 2010). A microgrid could be used in conjunction with a smart grid or could be used alone to enhance reliability of the electricity grid. Microgrids are designed to incorporate the different energy sources to meet the exact needs of the consumer, maximizing the quality and efficiency of the energy network. Simply put, microgrids would decentralize the grid to provide flexible options in the case of decreased power output, or provide a way of working around power outages. These small locally generated power systems could range from small fuel cells to microturbines to various forms of renewable energy.

A microgrid system offers a stress reduction on the overall energy system and an increased reliability because each power source acts as a back up to the others in case one fails or is producing much less energy. Microgrids can also encompass smart technology, thereby creating a smart microgrid or a smart grid with multiple energy sources. As explained by the Galvin Electricity Initiative, "smart microgrids leverage the bulk power system to take advantage of the lower cost base load power and remote renewable resources" (The Galvin Project, Inc., 2010). This would mean a smart grid could optimize what sources should produce more or less power based on energy demands and production expense of that source.

One company that is interested in installing a microgrid system on Nantucket, Viridity Energy proposes that they can evaluate each of their client's energy load and propose, "ways in which load can be shifted or curtailed to optimize the client's energy usage and to generate revenue" (Viridity Energy, 2010). The software that Viridity uses, simulates a model of the client's particular system including buildings, generators, distributed energy, and renewable energy assets and optimizes the cost/ benefit analysis of using various resources. For Nantucket, Viridity is proposing to control the electricity peak by managing energy use in the participating facilities at critical times, shift consumption to less-expensive off-peak, and integrate renewable energy resources such as wind or solar. This of course would only work if the utility, National Grid, or another utility provider offered a time-of-use rate based on peak loads in the grid they operate. There would need to be some infrastructure such as a smart meter to measure smaller daily increments of energy use in the middle of the day due to the high use of electricity at certain companies. To produce that high quantity of energy, power facilities need to increase the production of their generators causing them to function at a less than optimal rate, thereby increasing the price of electricity. By steadying the electricity peak a little, the power plants will be able to cut costs of production and decrease the price of electricity. Viridity plans on shaving the peak of electricity by using energy storage technology such as batteries, electric vehicles, thermal storage, and AC chillers to store energy during off-peak times and to use during peak times. This has been effective in Viridity pilot studies at universities across the United States in combination with dynamic pricing as explained in the previous smart grid section. This would require more infrastructures however, very similar to smart grids (Optimized Energy Networks, LLC, 2010).

Conclusion

Nantucket has many options to curtail its costly energy prices. The town could decide to proceed with an emphasis to promote conservation efforts throughout the town, continue further with renewable energy sources, incorporate smart grid technology, combine these options in various arrangements, or remain as is. An analysis of all options and various combinations of the options is needed in order for the Nantucket Energy Study Committee to make a decision on how to proceed further. The information provided in the Literature Review of is intended to help understand the energy issues of Nantucket begin an analysis of the various options for moving forward.

Methodology

Goals and Objectives

The overarching goal of the Feasibility of a Smart Grid on Nantucket Interactive Qualifying Project was to assist the Nantucket Energy Study Committee (NESC) in an evaluation of installing a smart grid on Nantucket. Other measures have been taken into consideration such as conservation efforts or renewable energy to compare costs and benefits to a smart grid. These measures were also analyzed in combination with a smart grid. The four objectives of this project were: (1) to evaluate the current energy profile and initiatives of Nantucket; (2) to analyze the effect of conservation efforts on Nantucket; (3) to project the effect of renewable energy on Nantucket; and (4) to identify the potential for smart grids and recommendations for Nantucket.

Tasks

Our project required various tasks such as research, interviews, surveys, and analysis. The table below demonstrates how our main tasks tied in to the four objectives (see Table 5). Interviews were conducted in the following procedure.

Tasks	Objective 1: Current Energy Profile and Initiatives	Objective 2: Effect of Conservation	Objective 3: Projection of Renewable Energy	Objective 4: Potential of Smart Grids
Literature Review	X	X	X	X
Contact Utility Company	X		X	X
Analyze Aggregate Electrical Data	X	X	X	X
Interview Energy Consumers	X			
Interview Island Energy Experts	X		X	
Interview Smart Grid Experts		X	X	X

Table 5: Project Tasks and Objectives

Interviews

Interviews were conducted to gain a well-informed understanding about the current use of electricity of major energy sources as well as to gain insight from experts in the smart grid field. We defined experts in smart grids as anyone who has extensive knowledge or a strong background on the topic of smart grids. Before each interview, the team created a list of questions to bring to each interviewee based on types of information we had hoped to gain. Most interviews were attended by at least two people. At the beginning of each interview, we began by introducing our project and ourselves and proceeding with the interview. Each interview lasted approximately 30 minutes.

For selecting who we interviewed, we used the "snowball sample" technique, starting with our project liaisons, asking who they thought we should interview next for the purpose of our project. We began contacting each suggestion by phone, introducing our project and purpose before setting up an interview. The majority replied in favor. After each interview, we asked if they would recommend someone to interview for the same purpose.

Objective 1: Evaluate Current Energy Profile and Initiatives

Our first objective was to evaluate the current energy consumption and current conservation efforts of the island. This objective helped provide a basis of electrical energy consumption on Nantucket and what consumers are currently doing to alleviate the high electricity costs.

Collecting Aggregate Consumption Data

One of the fundamental pieces of information needed to complete an energy profile of the town of Nantucket was past and present aggregate data on electricity on the island. The town of Nantucket had no aggregate data on current or past island-wide consumption of electricity. Therefore, our team sought out such data from the Nantucket electric utility company, National Grid. After emailing multiple contacts within National Grid, we were informed that we were denied access to the island's current aggregate energy consumption because the data was considered proprietary and confidential.

After some time, one of our contacts, a consultant for Nantucket, referred us to the Massachusetts Department of Energy Resources (DOER) website, which provided aggregate monthly totals of various classes of users (known as "Electric Customer Migration Data") for individual counties in Massachusetts. Each excel table was composed of the aggregate consumption by each of several different energy sectors: residential (R-1 & R-2), small commercial and industrial (G-1), medium commercial and industrial (G-2), large commercial and industrial (G-3), and streetlights (S-1) (See Appendix 4: Aggregate Data from the Electric Migration Reports). Found in this data was how many customers each sector had and how much total energy each section used. This data will be referred to as the aggregate data. With the aggregate data, we were able to calculate the average monthly electricity use of each customer in a certain sector. However, many of the results were very low which caused some concern that it was not accurate because of many seasonal meters or meters used in low energy settings such as a shed. What the graph did show was higher per capita electricity consumption in the winter due to the increased amount of space heating.

Surveys

Before we obtained the information about aggregate and municipal data, we began to survey the residential population about electrical data it used. We spent a majority of our first three weeks on the island carrying out residential (See Appendix 10: Residential Surveys) and commercial surveys about how they used energy and how much energy (in kWh) they used per month. This required asking for homeowners, or commercial establishment owners' electrical bills that have listings of monthly kWh data for the previous year.

The town Assessor, Deborah Dilworth, helped in gathering a random selection of houses to poll on electricity use. We found it very difficult to gather information about residential electricity use, as many people were not home, did not have their bill accessible, or did not want to share their bills with us. With this data we were going to calculate how much energy an average resident used and how much energy a building used per square foot and adapt it to the entire island.

Commercial establishments were much more likely to participate and seemed eager about the idea of a smart grid possibly reducing the price of electricity. However, it was very difficult to classify various commercial users. This posed a problem in gathering up users, analyzing, and adapting the information. After discovering the aggregate data was available on the Department of Energy Resources website, we decided not to continue with the route of surveys.

Estimating Number of People on Nantucket

Nantucket had no accurate estimates or graphs of how the island population varied by month, so we projected the results based on the solid municipal waste measured by the town's

Department of Public Works (DPW). Because there is only one place to take all the trash created on the island, the DPW can measure all the waste created on the island per month. By looking at the past 4 years of solid municipal waste data, provided by the Nantucket DPW, and relating the lowest trash-producing month (February) to the census data (which was predicted to be low) we calculated how much trash was used per person then we calculated from that value how many people were creating waste on the island by the DPW tons of solid municipal waste. This is all based off of one month and a prediction that the lowest trash-producing month in the off-season when many people go on February vacation will correlate with a lower predicted resident population.

Municipal Electricity Consumption Data

A consultant who worked for the town of Nantucket gave the municipal building data to us. The data was reorganized, and graphs were created in order to analyze the municipal data. The municipal data is a supplement to the aggregate data. When examining the municipal data alongside the aggregate data, use caution since the aggregate totals include the array of small, medium and large buildings owned by the municipality. We could not extract the municipal from the aggregate but we can add the entirety of the commercial/industrial sectors together and subtract out the municipal, but that required us to lump all the commercial /industrial together in our profile. Combining the small, medium, large commercial/industrial sections together was not in our best interest because we were able to collect data on each separate sector and review how each sector is different beyond there different energy use levels. Therefore in our analysis the municipal electric use is separate from the aggregate electric use but still a portion of the overall profile of the island.

Interval Data for Nantucket Island

With much correspondence with National Grid, one of our contacts was able to supply us with the interval data of the entire island. This was helpful in providing information on daily loads during the summer and winter. We took this data and graphed the summer peaks and winter peaks to demonstrate the upward trend of power peaks and projected it forward to when a third cable would be needed. We knew the max capacity from the cable and the buffer for which a cable would need in order to supply the max load.

Interval Data for Large Commercial Users

Interval data is only recorded for the largest commercial users (G-3) that use over a certain amount of energy every month. We asked the town of Nantucket to request a year's worth of 15-minute interval data for the town owned large commercial users from National Grid. The town clerk, Gregg Tina, approved the interval data request form and the town provided the base fee. Unfortunately this data did not arrive in time to be recorded in our report but will be available to the town in the future for its own benefit.

Interview Large Energy Consumers

In order to understand the largest energy users on the island, we spoke to representatives of the large energy consumers on the island to discuss their energy use. We identified the largest users when we were provided the aggregate and municipal data. We wanted to obtain information about what consumes the most power, at what times of day and how often is it used. We were also interested in learning more about the current conservation initiatives they were taking in their business as well as their individual energy consumption data from their monthly electric bills. These interviews were in lieu of a residential survey we had planned to undertake before we were aware of the aggregate consumption data collected by DOER (for information on residential surveys see Appendix 11: Residential Survey). Instead we decided to interview the commercial energy consumers because large commercial establishments have a large impact on the electricity grid peaks at different times of the day depending on the equipment used.

Interview Island Electrical Energy Experts

In reference to island electrical energy exerts, expert refers to someone who is knowledgeable about the energy problems on Nantucket. We spoke with a number of members of the Nantucket Energy Study Committee as well as representatives of ReMain Nantucket, both of which are involved in conservation and renewable projects on the island. These interviews supplied us with the island's potential generation power as well as an awareness of the size and nature of the conservation movement on the island. We acquired much knowledge that was useful about current conservation and renewable efforts on the island, which could be incorporated into later objectives. Through this we gained some understanding of the island-wide conservation movements beyond the direct consumer initiatives.

Objective 2: Analyze the Effect of Conservation Efforts

Conservation of electricity has been identified as a potential option to solve Nantucket's electric problems. In order to appropriately estimate the potential use and cost savings the island would experience, we first needed to research the concept. We chose to look at both simple conservation methods, such as installing programmable thermostats and compact fluorescent light bulbs, as well as more involved methods of conservation, such as installing a geothermal HVAC system, and checking the efficiency of an HVAC system. Once our group acquired reduction percentages of each conservation method, we applied the reductions to the current electrical use of each of the island sectors separately and all together in an aggregate form.

In order to ensure the accuracy of our reduction factors, we required that our figures be supported by at least two verifiable sources and that they are reasonable estimates based on our knowledge of human behavior. When conducting our cost and use reduction estimates, we used the data available ranging from 2008 through August of 2010, and applied the reductions both individually as well as in some sequential order. The reductions were applied first individually so that we could explore the effectiveness of any single conservation method with respect to the other methods. We then chose three conservation methods that were identified as easiest for the Town of Nantucket to implement: (1) installing programmable thermostats, (2) converting all lights to compact fluorescent light bulbs, and (3) unplugging all unused appliances. In order to determine ease of implementation, our group took into account how expensive the upfront costs were, and how likely individuals would be to follow the conservation tactics in their home.

Each conservation method projection was completed in Microsoft Excel, and multiple graphs showed us exactly which methods were the most plausible. Once the cost and use reduction evaluations were completed for each scenario, we compared each situation with all of the other conservation tactics as well as our business-as-usual and smart grid models. We used this analysis to further our understanding of reduction possibilities and to provide further credibility for our final conclusions and recommendations.

By analyzing the soft data collected throughout interviews as well as the hard data that was found in reports we established the pros and cons of each possible smart grid, taking into account the demographic of the island and the electric consumption.

Objective 3: Project the Effect of Renewable Energy

Nantucket has already implemented some renewable energy and plans to implement more in the future. In order to analyze the effects renewable energy will have on the monthly aggregate peaks and valleys of energy consumption we needed monthly data of how much energy each existing or proposed renewable energy source would produce.

We began by analyzing how much wind energy would be produced for the town between the existing 100kW high school turbine and the proposed 1.5MW Madaket landfill turbine. Both were calculated using annual predictions of how much energy they produce per year and wind averages per month taken from the Nantucket High School Wind Final Feasibility Study (Alteris Renewables, n.d.). The wind data were collected from July 22, 2005 to August 31, 2006 at hourly intervals at 3 different heights (none being the height of either turbine). We averaged the wind speeds for each height to find the average wind speed in each month. We will call this the average monthly wind speed. We also took the average of all of the months. We will call this the average wind speed. Then we took the ratio of the average monthly wind speeds over the average wind speed and multiplied by the predicted annual amount of energy produced by the turbine to get energy production per month. We used the same process in calculating the amount of wind energy the Madaket turbine would produce on a monthly basis.

Next, we needed to calculate how much solar energy could be produced by month. Preferably, we would have liked to see a report done on solar on Nantucket, but we had no such reliable information. When we discussed this with our sponsor, Whitey Willauer, he made his own projections based on the declination of the sun, and hours of daylight available. He later provided us with an Axio Power Report for the same type of 2 MW solar panels in Greenfield, Massachusetts. As this is in the state of Massachusetts, we used the same data for the analysis and results of what would happen here on Nantucket.

After collecting the data we analyzed what the energy profile of the past full year would look like with renewable energy with wind, solar and both. Then we looked at where the energy was feeding directly to see if electricity would need to be sold back to the grid at any time of the year.

Objective 4: Identify the Potential for Smart Grids and Recommendations

The smart grid analysis and results were compiled after telephone interviews with Rob Tullman, CEO of Granite Services (a wholly owned subsidiary of General Electric and part of the GE Energy business) and Doug Hurley, data systems expert from Synapse Energy Inc. After our conversations with them, which substantiated the evidence we had found during our literature review we were able to prepare a rough estimation of the effect smart grid could have on Nantucket and the future implementation steps. These are outlined in our results/analysis and recommendations.

We had hoped to contact many more experts in the field of smart grids at the beginning on the project, but due to the non-responsiveness of the companies we contacted we soon learned that the most valuable information we could collect about smart grids would have to come from the literature. Before beginning the analysis of smart grids we had to first collect the correct data. That consisted of a collection of cost/smart meter, electric reduction potential with smart grid and a deep understanding of National Grid electric rates. The data from the Migration Report, which was used to supplement our energy profile: a key in the calculations of smart grid.

In order to calculate reduction we had to know what the peaks on Nantucket were. Since we did not have daily load profiles for Nantucket's residential sector we converted the daily load profile of New Hampshire residents to match the monthly usage data of Nantucket. The assumption we made to do this was that New Hampshire and Nantucket share a similar geographic region and therefore weather patterns, which drive a large percentage of daily electric consumption patterns.

After converting New Hampshire Daily Load data into Nantucket Daily Load data we segregated the winter months (October-May) from the summer months (June-September). This segregation was based on the current smart grid program running in Boulder, Colorado. Once the months were separated we then extracted peak hours from the 24 hour data, consisting of 2pm-8pm. Once this was partitioned we took the total kWh of the four different sections, winter on and off peak, summer on and off peak.

With these four numeric sums we once again borrowed the rating system used in Boulder, Colorado smart grid and applied the cost/kWh to each of the four sectors. This supplied us with the cost of on/off and winter/summer power. We took the total kWh from the residential sector and multiplied that by the current National Grid residential rate to get the total cost of electric for the island operating business as usual. Then we compared the total cost of business as usual electric to the cost with the different rate structure. We found that these costs were very similar, proving that our analysis was accurate. Afterwards we took 5% of the on-peak power from winter and summer and moved it to the off-peak power totals and once again recalculated costs with the new distribution of kWh data. We ran the same scenario for 7%, 10% and 12% of on-peak kWh moved to off-peak kWh totals. This provided us with a simple TOU cost to residential consumers.

In order to calculate the cost of a smart grid we took the cost/ smart meter multiplied by the total residential meters (known from the migration report) to gain total capital cost. Then we added all the reductions that smart grid offers and applied it to the TOU cost we described calculating above. Savings were classified by comparing business as usual cost to the TOU cost * smart grid reductions.

The conservation costs and savings calculations are described in the previous section. Those were also added to the smart grid costs and savings to create a total picture of smart grid and conservation payback period together.

Results and Analysis

Current Nantucket Energy Profile

In order to successfully predict the potential savings a smart grid could provide Nantucket, we first needed to establish the current electricity use of the island. We needed to explore how much the island uses throughout the course of days, months and years, as well as to determine when the island uses the most electricity. Understanding the different usage patterns the Nantucket populous follow has allowed our group to better analyze the impact of smart grids. Seen below in Figure 10 is the aggregate total kilowatt-hour usage of all sectors from August 2001 to August 2010. There were two missing months, February 2007 and May 2010 in which a projection was made based off of the data from the other year. To make these projections we took the average increase from January to February or April to May and applied that to the ratio. Evidently, electricity consumption peaks in the summer months, and there is a small peak in the winter. The amount of electric consumption drastically increases during the summer, Nantucket's peak tourist season, in which the population swells to more than 50,000 people, and decreases drastically when the summer months are over. The summer peak may be explained by a number of things such as the drastic increase in population, increased used in air conditioning throughout the island, and use in high power technology. The winter peak is much smaller than in the summer, and is likely caused by the use of electrical heat in year-round residences as well as commercial establishments.

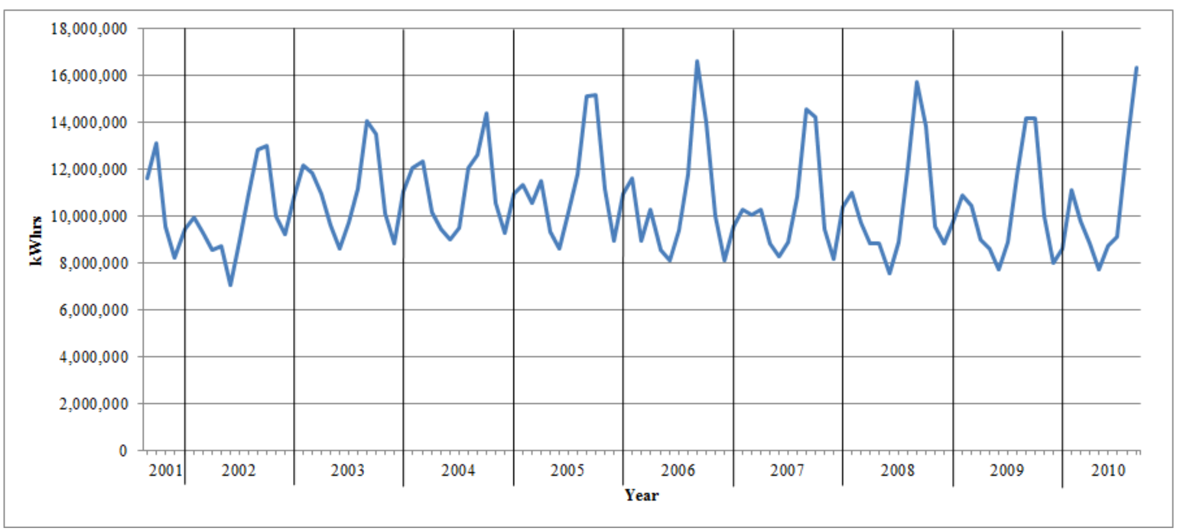

Figure 10: Nantucket total kilowatt-hour usage from August 2001 to August 2010
(Department of Energy, 2001-2010)

Another noticeable difference is that the range between the summer and winter peaks increases after 2006 due to an apparent reduction in the winter peak. This would seem to suggest permanent residents are conserving more energy following the price increases. After the year 2006 the peaks start to decrease. The second undersea cable was installed by the year 2006. As soon as the second cable was installed, the price of electricity also went up, which is one possible reason for the decrease in electric consumption over the next four years. Increases in the cost of electricity have made people a little bit more aware of how much electricity they are consuming. Another possible reason for the decrease in energy consumption could be that there was a decrease in the number of people who came to this island due to the recession in the economy.

Below, Figure 11 plots the total electrical consumption (MW) in the peak month of each year between 2001 and 2010 (typically, the peak month is August or September). A linear trend line was also added to the graph, and extended ten years into the future.

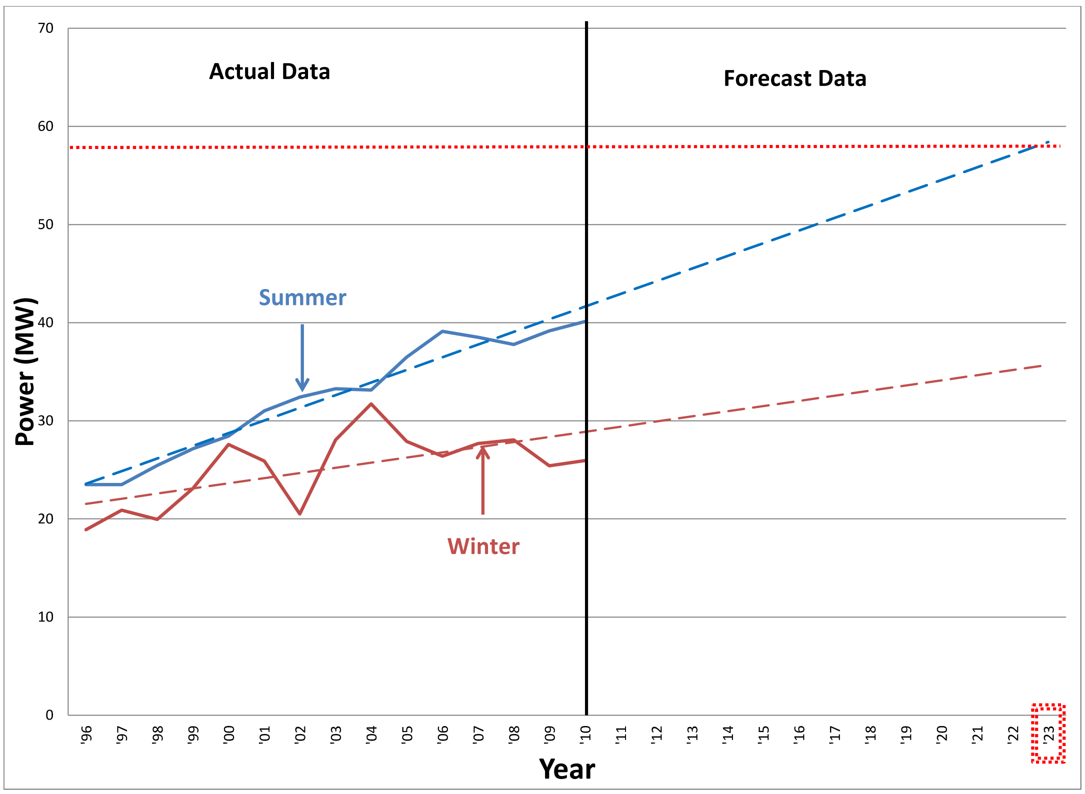

Figure 11: Projection of Nantucket Annual Electrical Power Peak (MW)

The island electrical power peaks are important, because they are the driving force behind whether or not the town will need to secure a reserve capacity (e.g., a spare generating plant or a

3rd undersea cable) in order to meet instantaneous peak demand. The above graph displays the projection of the summer and winter power peaks on Nantucket. When the projections reach 58 MW, within 17% of the max capacity of the cable, the cable begins to fail and cause blackouts and brownouts. This information provides a good basis for when a cable would be necessary on Nantucket if energy consumption continues rising and nothing is done to curtail it.

Creating an Energy Profile

Before any recommendations for smart grids and other electric conservation tactics could be made, we found it necessary to create an energy profile of the island. This profile is broken up by energy sectors according to National Grid classifications. The four energy sectors are: residential (R-1 & R-2), small commercial and industrial (G-1), medium commercial and industrial (G-2), and large commercial and industrial (G-3). The large town facilities (e.g., airport, schools, DPW) are the only G3 users, while the remainder of the town facilities are classified as G-2 facilities. The remaining G-1 and G-2 users comprise many different types of establishments, such as Nantucket Island Resorts, innkeepers, supermarkets, and retail stores. Finally, the residential sector of Nantucket comprises what is known as the Massachusetts decentralized decision makers, and is also the group of users that populate the R-1 and R-2 energy sectors. Each sector necessitates distinctive modes of approach and may be amenable to distinctive interventions. We also chose to include a section on the municipality buildings for the town.

Figure 12 shows aggregate monthly electricity consumption (kWh) in each major sector between August 2001 and August 2010.The streetlight sector was excluded since it is small consumer of electricity covered by the town budget. Data for the large commercial and industrial sector are missing between late 2007 and 2008.

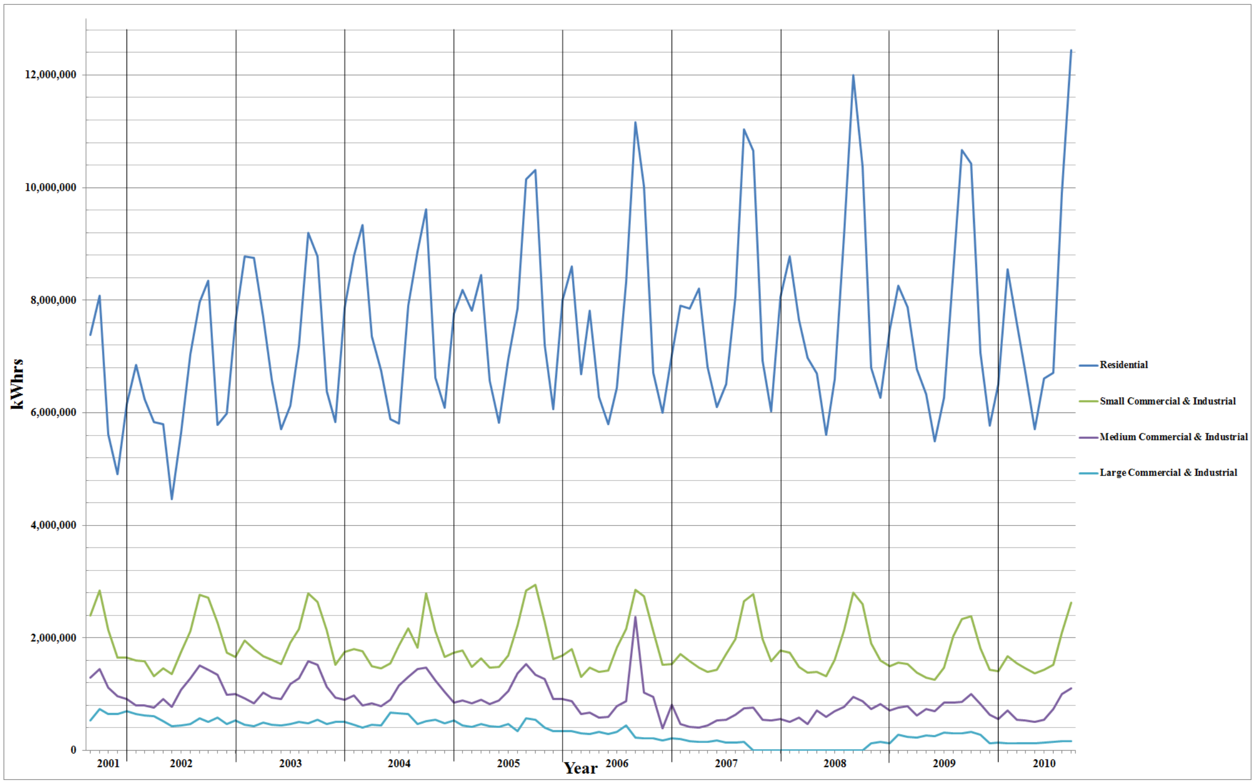

Figure 12: Aggregate kWh Usage from August 2001 to August 2010
(Department of Energy Resources, 2001-2010)

Figure 12, above, shows dramatically that the residential sector consumes most of the electricity on the island, while large commercial and industrial buildings consume a small and declining amount. Together the residential and small commercial and industrial sectors are responsible for the substantial summer peak in electricity consumption, and the slightly smaller winter peak. These peaks likely reflect visitor numbers. The declining consumption of large commercial and industrial may reflect aggressive efforts in energy conservation or they may be symptomatic of long-term economic activity. Small commercial and industrial facilities (such as retailers and restaurants) show no similar downward trend in consumption, and the summer and winter peaks remain remarkably consistent over the years. The largest consumption peaks for most commercial and industrial facilities show up in 2006, which happens to coincide with both an economic peak for the island, and the installation of the second cable. What drives peaks remains shrouded in uncertainty, but is most likely attributable to combination of weather, peaking of tourist and summer resident population.

Residential Users (R-1 and R-2)

The residential users consist of non-low income users as well as low-income users. Both are separate sectors, but are combined in order to make this analysis easier and more understandable. Low income users consume very little electricity overall and their usage varies minimally from month to month and year to year, so their impact on the overall pattern of energy use is negligible. The pie chart below (see Figure 13) shows the total energy consumption by each sector in 2009, and dramatically illustrates how the residential sector dominates the energy scene.

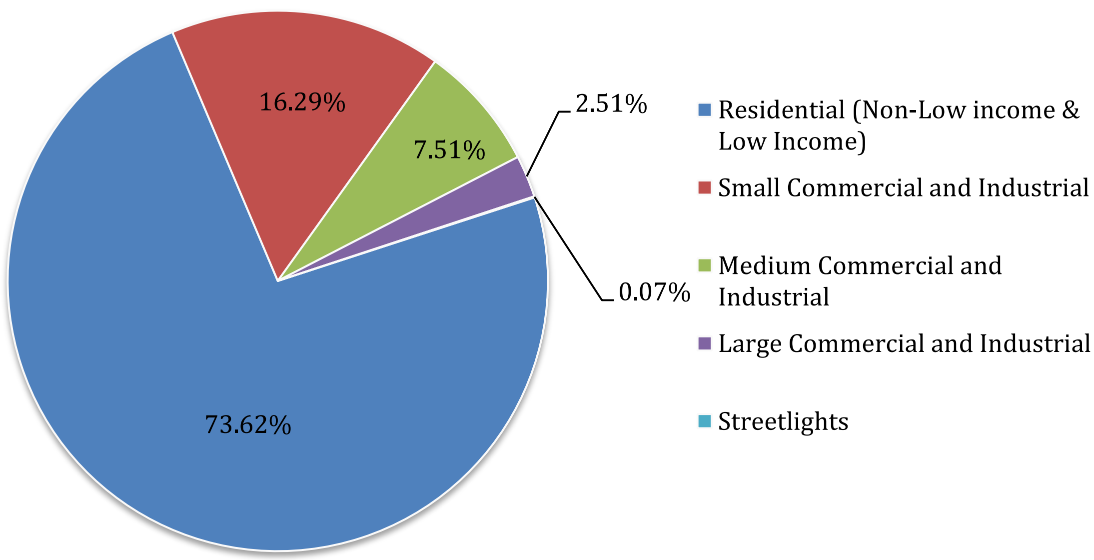

Figure 13: Pie Chart of Total Energy Consumption by Sector for 2009

Figure 14 reinforces the dominance of the residential sector. It shows the average annual consumption of electricity (kWh) between 2002 and 2009. In a typical year, the residential sector uses more electricity than all the other sectors combined.

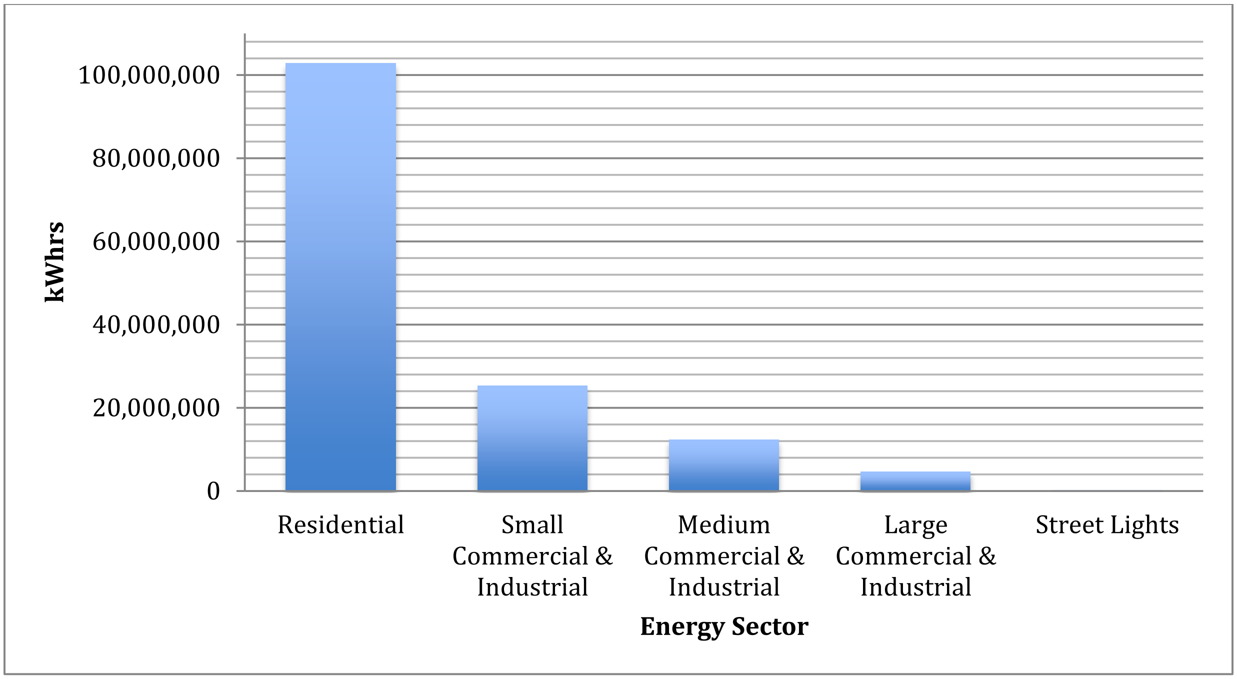

Figure 14: Bar Graph of Average Yearly Kilowatt Hour Usage from 2002 to 2009 (Department of Energy Resources, 2001-2010)

Small and Medium Commercial and Industrial Users (G-1 and G-2)

The second and third largest energy sectors are the small and medium commercial and industrial users that include all the retail stores, restaurants, grocery stores, inns, museums, and other similar establishments. Figure 12 shows that peak consumption for the small commercial and industrial sector is relatively stable regardless of the increase in price of electricity due to the installation of the cable. The consumption for medium commercial and industrial users appeared to peak around the summer time from the years 2001 to 2005, and these users appear to have substantially moderated their peak summer consumption since that time, probably in response to rate increases following the installation of the second cable.

Large Commercial and Industrial Users (G-3)

The current identified G-3 users on Nantucket are the High School, Elementary School, Waste Water Treatment Plant, and the Madaket Solid Waste Facility, and the Nantucket Airport. The G-3 users on the island may represent a small portion of the total consumption on the island, but each facility uses a large amount of electricity by itself. Each G-3 user is different, and each has different purposes, facilities, and equipment associated with them.

The figure below shows the energy consumption of the Nantucket High School and the Nantucket Elementary School in kilowatt-hours from August 2008 to September 2010 (see Figure 15). The high school appears to use considerably more electricity than the elementary school, but these data also include the electricity used in the community pool and middle school that are next door.

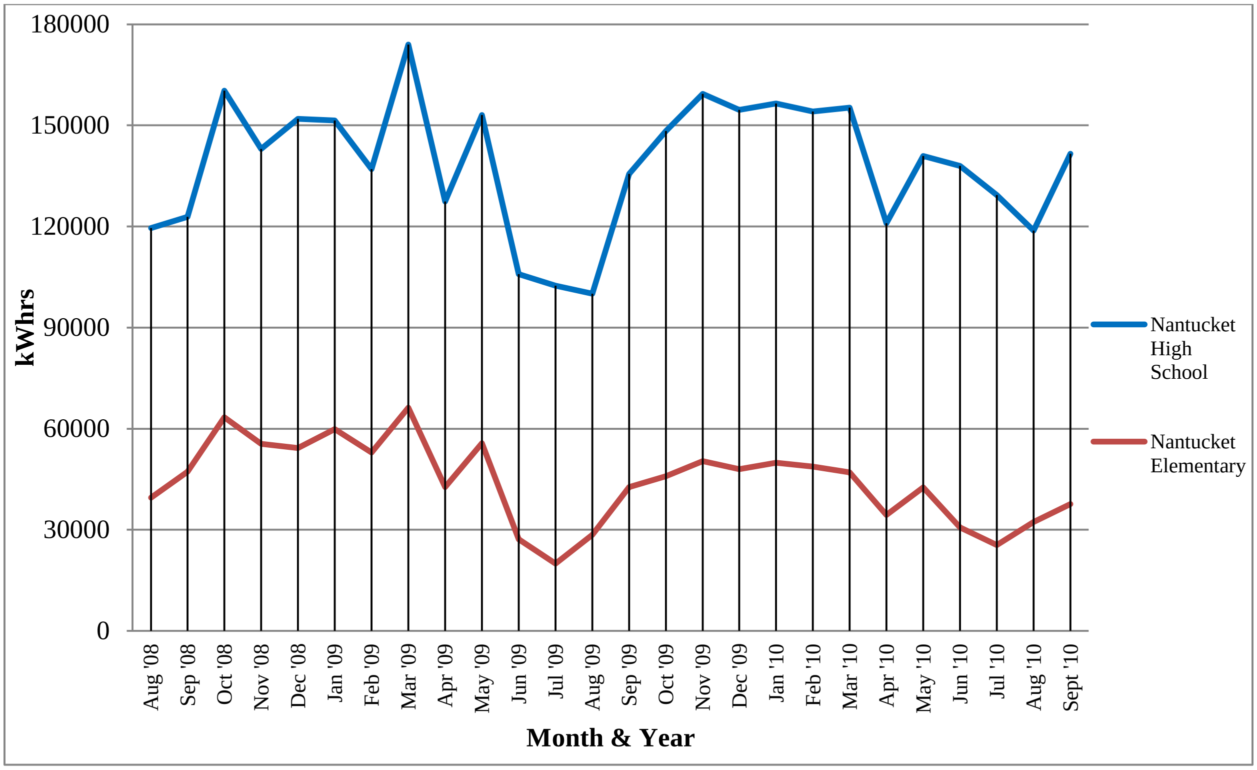

Figure 15: Nantucket High School and the Nantucket Elementary School Energy Use

Even though there is a large gap between the high school and the elementary school, the peaks and shapes of the lines are still similar. Both schools have the unsurprising drop in electricity during the summer months, because both schools are not in session. There are also small drops in consumption for February and April in both 2009 and 2010 since there are week long vacations during these months. Other peaks and valleys probably result from changes in the weather and thus variations in heating and cooling demands.

Two other major G-3 users are under the control of the town DPW and are the Madaket solid waste facility and the wastewater treatment facility. The graph below compares the electric consumption in kilowatt-hours of the Madaket solid waste facility and the wastewater treatment plant from August 2008 to September 2010 (See Figure 16). Both G-3 facilities are part of the Nantucket Department of Public Works (DPW). According to the director of the DPW, the significant drop in electric consumption at the wastewater facility from August 2008 to April 2009 happened because during that time period, the facility was in the process of being rebuilt in order to increase efficiency the facility's efficiency.

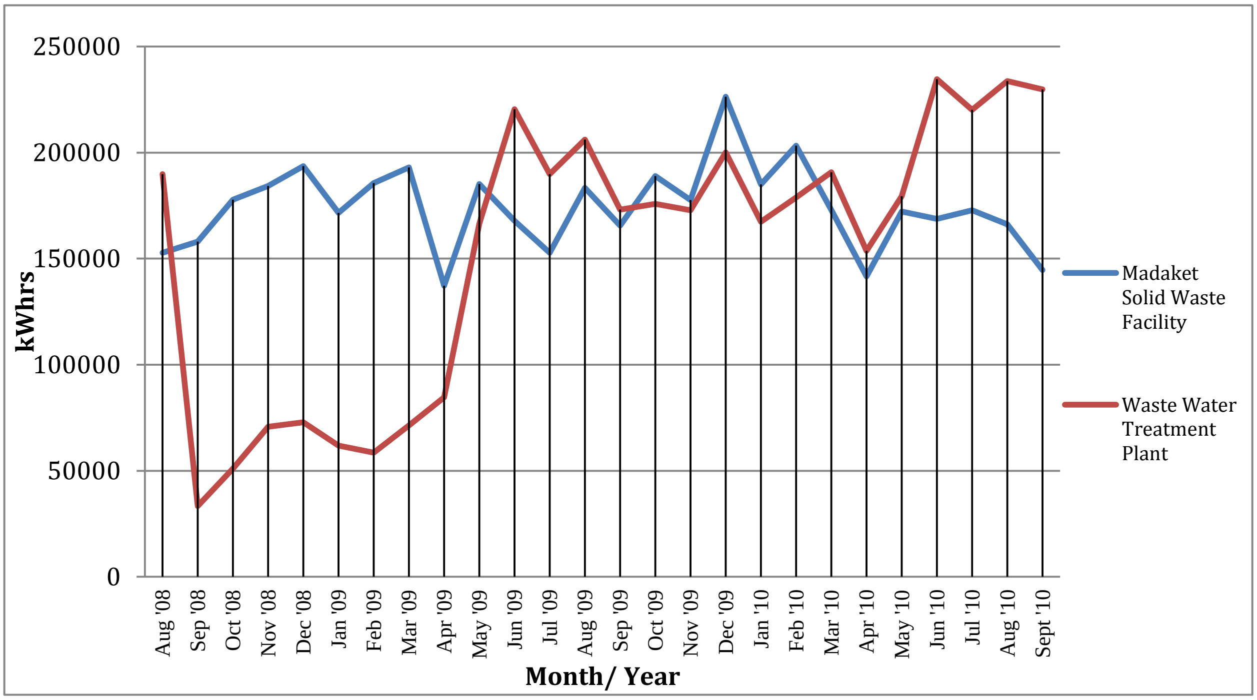

Figure 16: Energy Consumption of the Madaket Solid Waste Facility and the Waste Water Treatment Plant

Other than the drop in consumption for the wastewater treatment facility, the peaks appear to reflect the tourist population, although the peaks are much less distinct than those in the residential sector. The consumption for the wastewater increased greatly for the 2010 summer. The Madaket solid waste does not appear to have a pattern with the peaks; this may be due to the recent renovation. Therefore, the data we have is not substantial enough to draw a conclusion.

The fifth G-3 user on the island of Nantucket is the Airport. Figure 17 illustrates the electric consumption in kilowatt-hours of the Nantucket Airport from August 2008 to September 2010. Over the course of the two years, total consumption at the airport appears to be increasing. A possible reason for this would be the increased number of people who visit the island each year. There are greater peaks in the wintertime than in the summer time due to a lower year-round population, and therefore fewer populous to fly in and out of Nantucket.

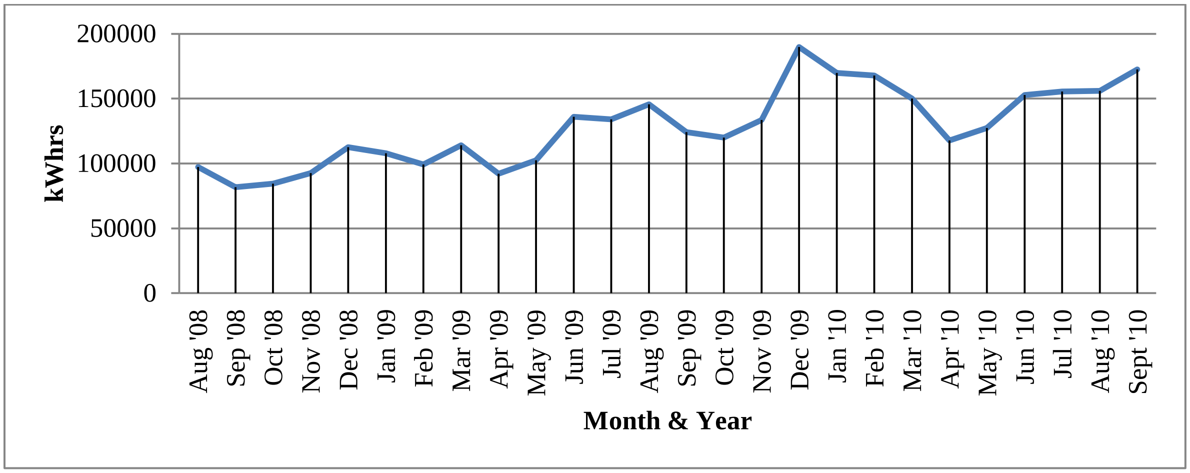

Figure 17: Nantucket Airport Energy Consumption

Even though the large commercial and industrial sector accounts for a small proportion of total electricity consumption compared with the other sectors, the town owns four of the five G-3 facilities on the island and may therefore have more control over the consumption.

Municipality Buildings

The Town controls most of the large commercial and industrial users (G-3) on the island as well as several of the G-1 and G-2 users. The graph below shows the electric consumption for each municipal facility in the town from August 2008 to September 2010 (See Figure 18). The different municipal facilities include the Town offices, Nantucket Department of Public Works (DPW), the airport, the public schools, the fire department, the water distribution facilities, and the Nantucket Regional Transit Authority (NRTA).

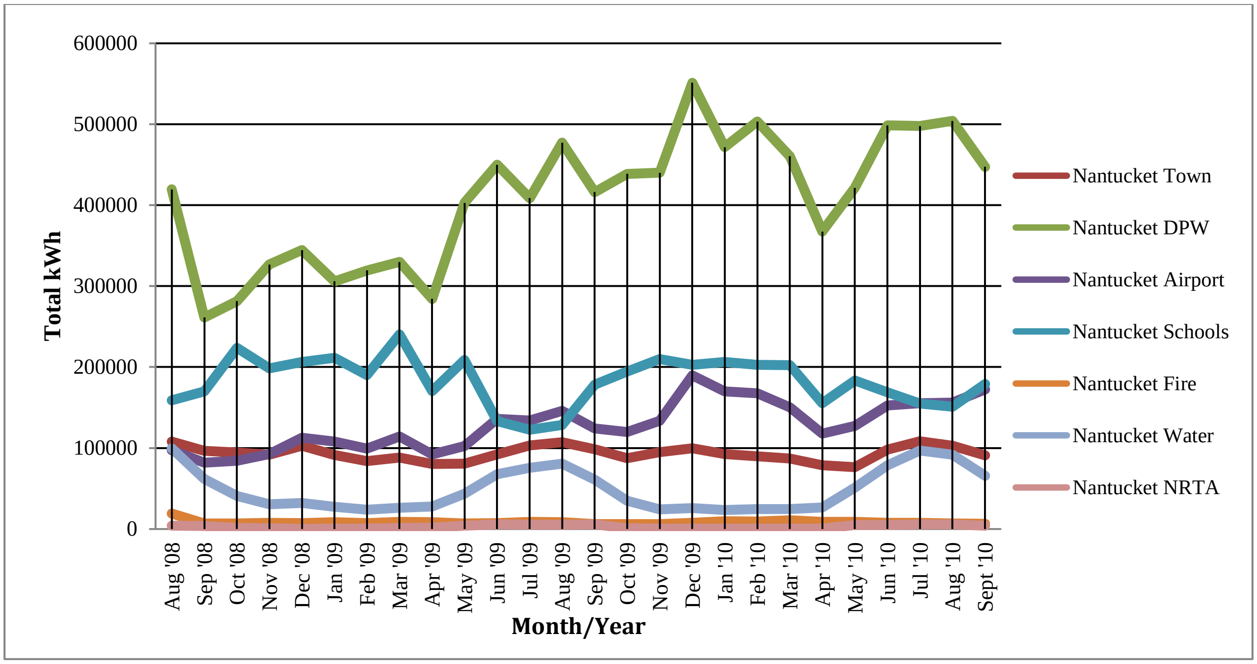

Figure 18: Total kWh Usage of Municipal Facilities from August 2008

Figure 18 shows that the fire station and the NRTA are very low energy consumers compared to the other municipal facilities. The greatest municipal energy consumer is the Nantucket DPW, because they are responsible for two of the five large commercial and industrial facilities, which are the Madaket Solid Waste Facility and the wastewater treatment facility. Electric usage from the DPW has increased greatly since 2008. The largest peak in consumption was in December of 2009, which may be reflective of the hiccups in energy consumption due to the renovation. The director of the DPW informed us that a possible reason for the peak could also be most of their facilities have electric heat during the wintertime, this may be an average winter peak for them since the '08 data is not indicative of actual usage due to construction on the site. The consumption by the Town offices is very stable except for the small peak during the summertime possibly due to the use of air conditioners. Consumption from the water company reflects the population increase during the summertime. The airport is another G-3 user as its consumption appears to be close to the consumption of both schools added together throughout 2009.

The profile reveals the island of Nantucket is a unique place in terms of energy consumption. The islands population is what drives up power demand. A more efficient grid would benefit the residential, small commercial and industrial, and medium commercial and industrial sectors. The large G-3 user may also benefit from a smart grid, but not as much as the other energy sectors because the G-3 users on the island already have time-of-use rates where their prices are dependent upon when there is peak demand. Since these large facilities have more control than the other sectors they may benefit more through conservation tactics.

Nantucket Population

We calculated the population on the island because the town census only captures the year-round residents (and possibly not migrant workers) and other entities estimates of population are not based on data. We needed an accurate estimate of population in order to specifically calculate energy use per person on the island as well as draw other conclusions per capita. From our interviews with many of the town residents and employees of the town such as our sponsor Whitey Willauer, and the Town Clerk's office, we have found that the number of year round residents is relatively stable (at about 10 to 11 thousand persons) from year to year. However, many people live on the island for just the summer, or the summer until the end of December. The months when there are not many visitors on the island are months such as February and March. By looking at the past 4 years of solid municipal waste data, provided by the Nantucket DPW, and relating the lowest month to the census data we calculated estimates of total population on the island by month and year as shown in the graph below (See Figure 19).

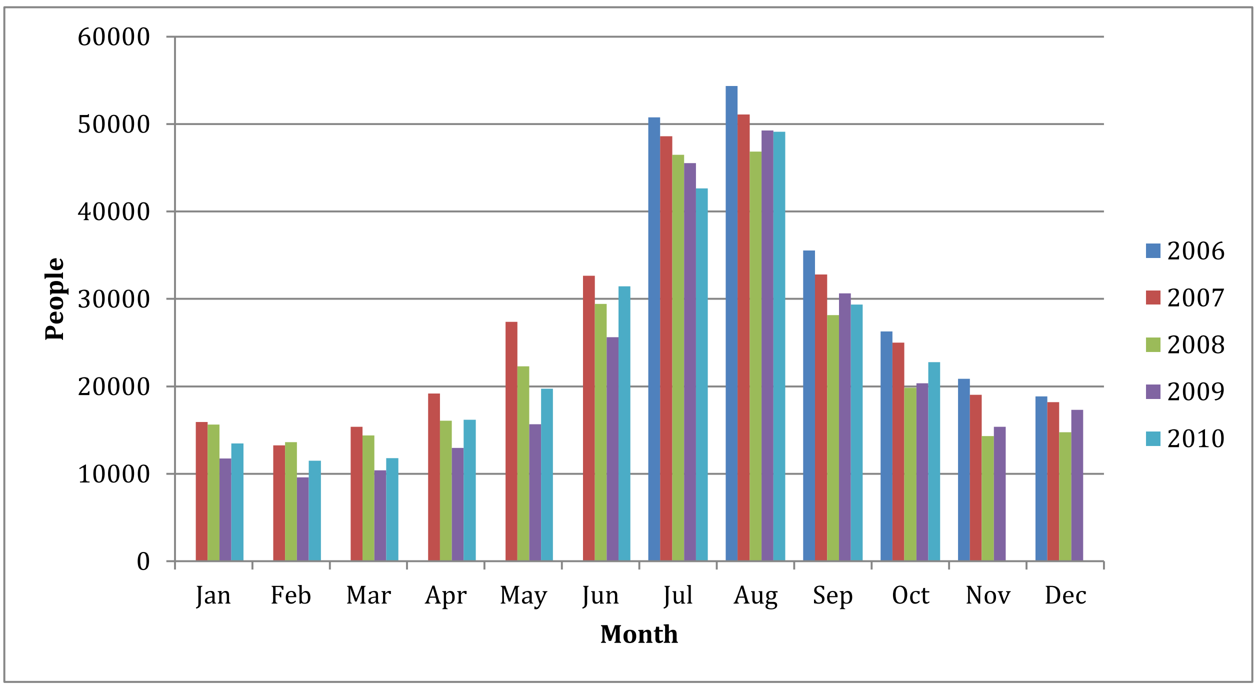

Figure 19: Estimates of Nantucket's Combined Full-time and Seasonal Population, by Month: 2006-2010

Figure 19 also shows an annual surge of 45,000-53,000 people in residence during peak season on the island. The graph also shows that the number of people visiting the island has slowed steadily since 2006 but has been on the rise in the last year. This may be due to hurting economic times, or could have more to do with there being less waste and more recycling per person up until the current year, thereby skewing the graph. While this graph may not be the most accurate, it is the most precise and extensive measurement of the number of people on the island we have to base calculations on. This must be considered when analyzing calculations based on these estimates.

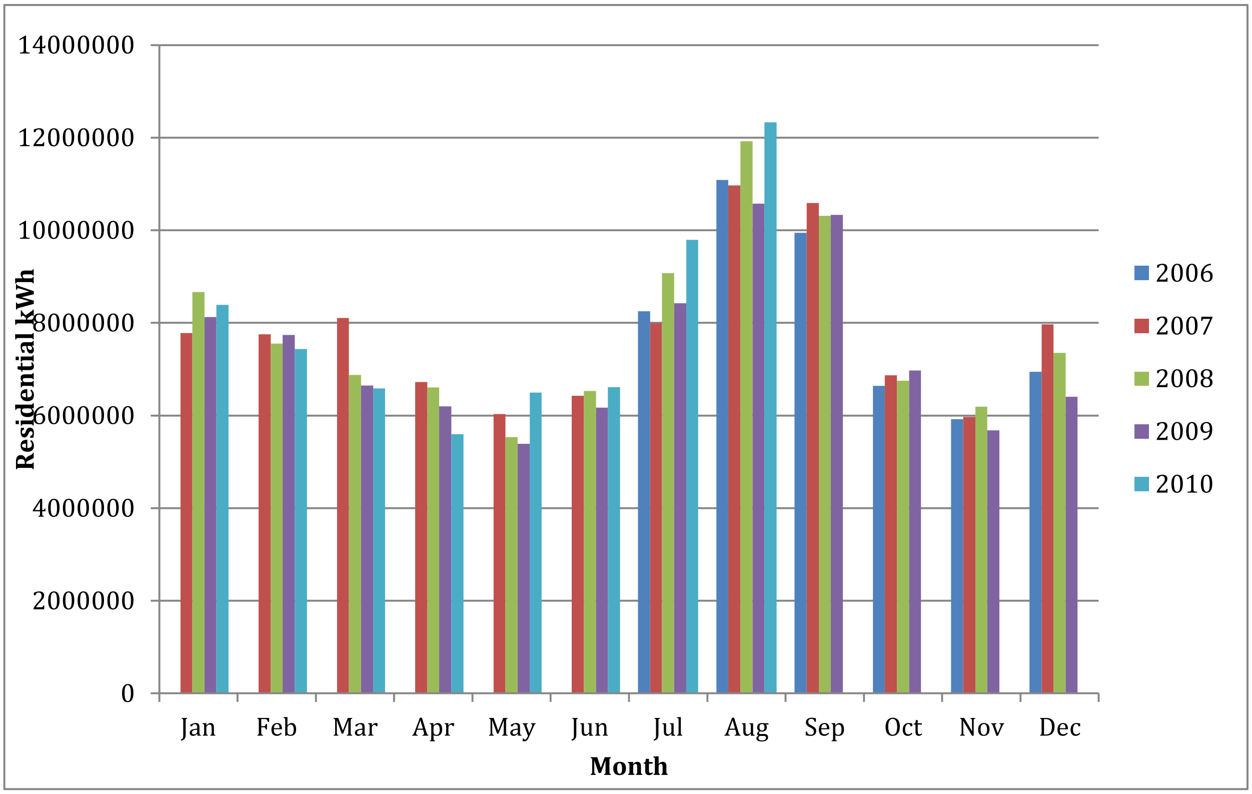

Figure 20: kWh Used in the Residential Sector by Year

As shown in the graph above, the peak of residential electricity is typically in the summer month of August (see Figure 20). This is probably due to the large influx of people on the island in high tourist season and the steadily rising use of air conditioning. It appears, however, that the average monthly consumption of electricity per person has been increasing over time in the summer months. Based on conversations with residents, this may reflect the growing use of air conditioning in summer. According to the Department of Energy's New England Household Electricity Report (2005), only 9.3% of all New England homes use electricity for space heating.

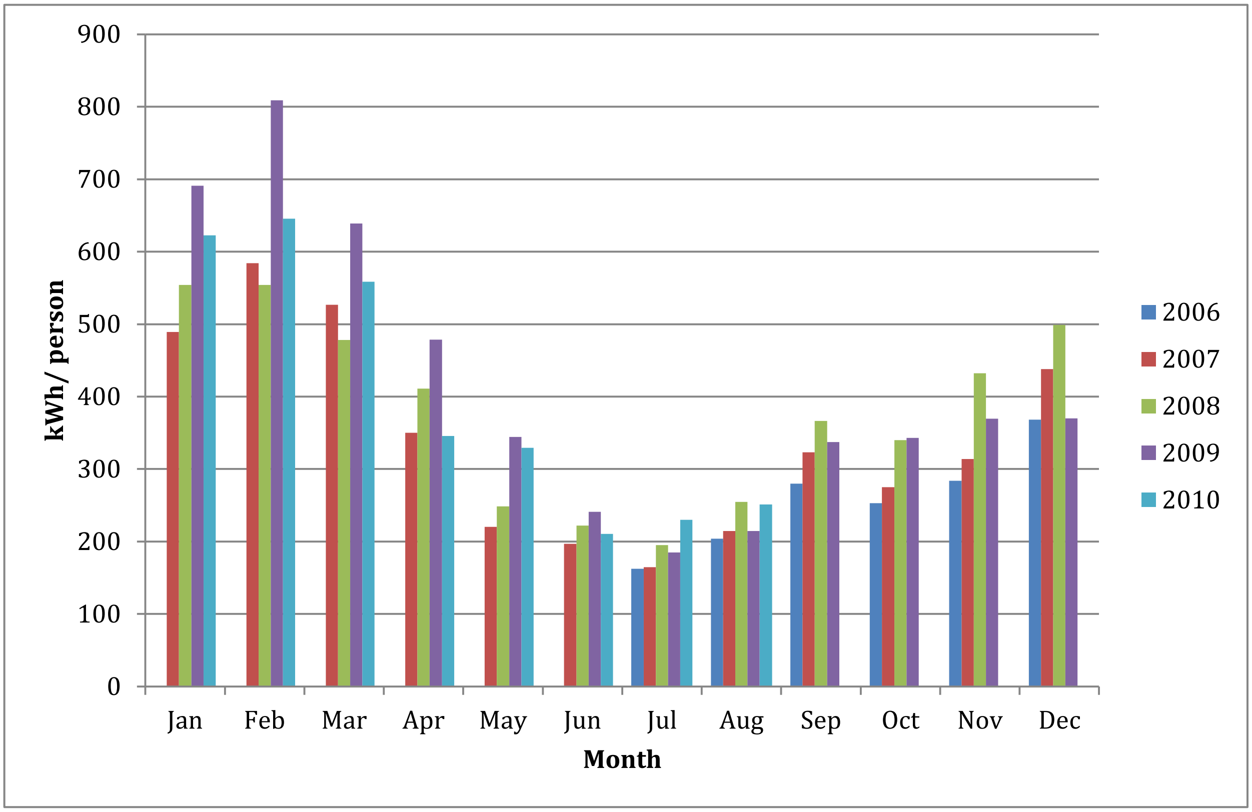

Figure 21: kWh Used Per Person in the Residential Sector by Month

Figure 21 shows how much of an effect space heating has on per capita electricity use. Electric heating on the island appears to be prevalent, despite the information gained through interviews, which contrarily mentioned people have been reverting to gas heat. Many people visiting Nantucket are just day travelers, and do not use any electricity in the residential sector during the summer, which may explain the low per capita energy use. Also, while renting a house is common for long periods of time, many people choose to stay in a hotel or resort for short visits, which is classified in the Commercial sectors and would not be reflected in this graph.

Electric Generation Potential

As the island tried to address high energy costs, it has delved into renewable generation as a possibility for reduction potential. Although renewables do not directly affect the peak demand, they do lower demand when natural generation does occur.

Wind Turbine Electricity Generation

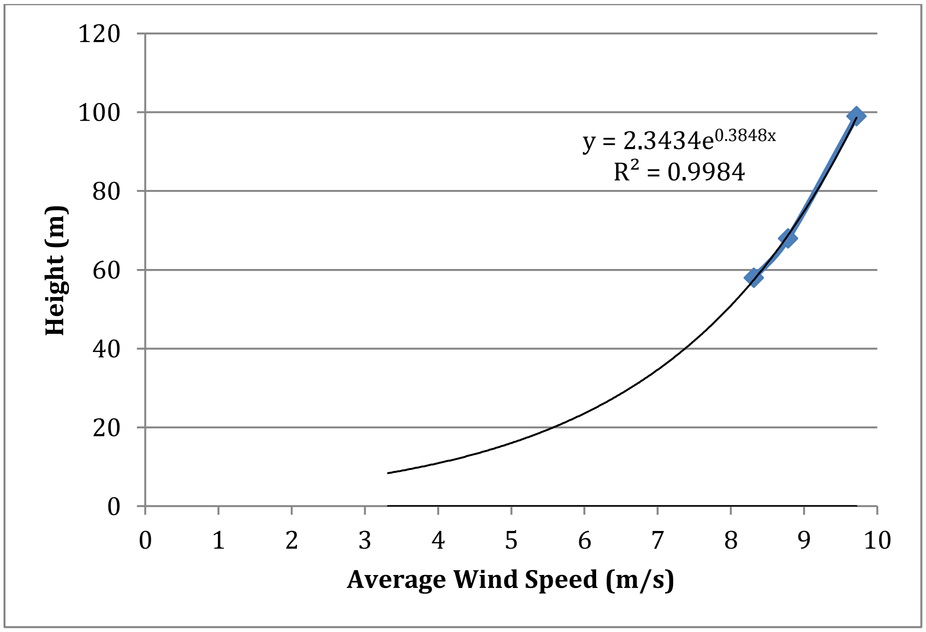

Figure 22: Average Wind Speed on Nantucket Based on Height from Ground Level

The data for the graph is based on hourly data from the Public Works tower at the Nantucket Landfill from September 2005 to August 2006 (see Figure 22) (Alteris Energy, 2010). The report is for the final feasibility study for the 100 kW wind turbine at the high school, a little over 3 miles away from the landfill. A 1500 kW wind turbine is proposed on the Nantucket Landfill property, but has not yet been approved for building.

Based on the trend line in Figure 27, the yearly average wind speed for the 37 meter high school turbine should be around 7.17 m/s. Based on the Alteris Energy report which factored in wind shear factor of 0.2 and designation class 1, the estimated wind resource would be around 5.42 m/s at the 37 meter hub height. The report projects that the 100 kW wind turbine will produce 192,000 kilowatt-hours annually for the school.

Reverse engineering data based on the report, we predicted how much energy the high school wind turbine produced per month as shown in Figure 28 below. To do this, we calculated wind averages per month, took the average of all months and divided by the total predicted kWh then multiplied by the monthly wind speeds.

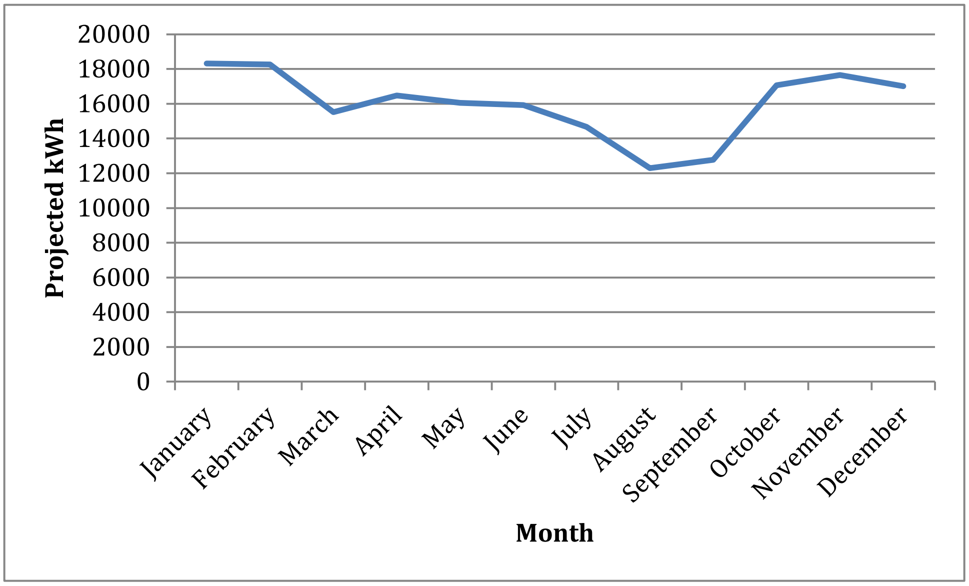

Figure 23: Predicted kWh Generated by Month at the High School Turbine

As you can see, the highest predicted energy generation is in the windiest months of October through February and the lowest energy generation is in the least windy months of July through September. This graph could be applied to almost any wind turbine on Nantucket as shown below with the turbine proposed for the Madaket Landfill. The predicted annual kWh average on Nantucket for the 1500 kW turbine was 4,730,000 kWh. Note that although the graph looks similar the axis varies greatly (See Figures 23 & 24).

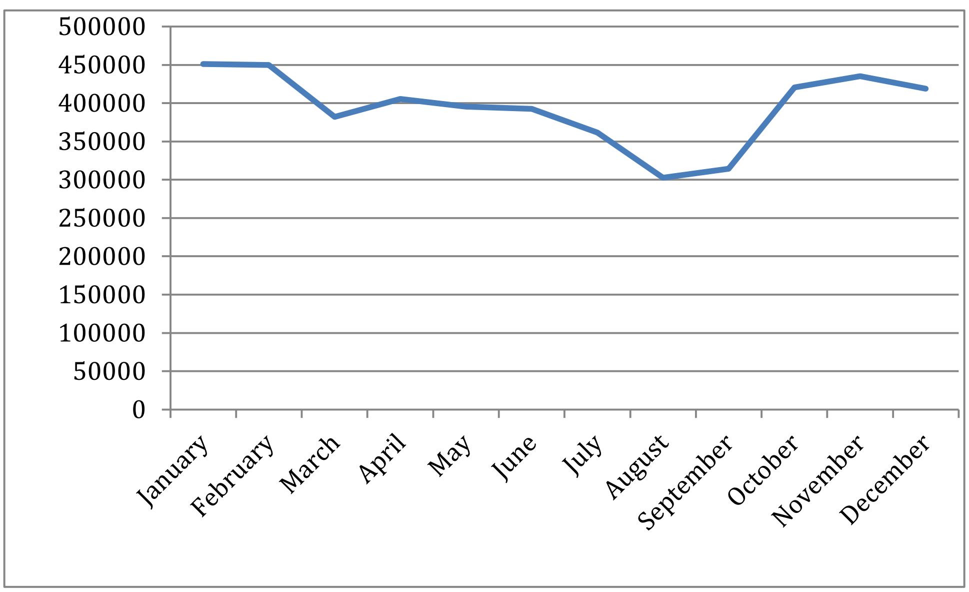

Figure 24: Predicted kWh Generated by Month Madaket Wind Turbine

Solar arrays also may contribute to softening the energy prices on Nantucket. There are many options the town may take. The town may choose lease 10 acres of land to a company to install solar arrays around large municipal facilities to provide them with the extra power they require. According to an analysis of the 10 acres of photovoltaic solar arrays, 2,415,860 kWh would be produced over the first full year (Paterson, 2010).

Solar Power Electricity Generation

The solar data in the graph below was all taken from results of a 2 MW turbine in Greenfield MA and is shown in the figure below (See Figure 25). To get a summary of the combined solar farms we multiplied by four because the town is looking into building four 2 MW solar farms.

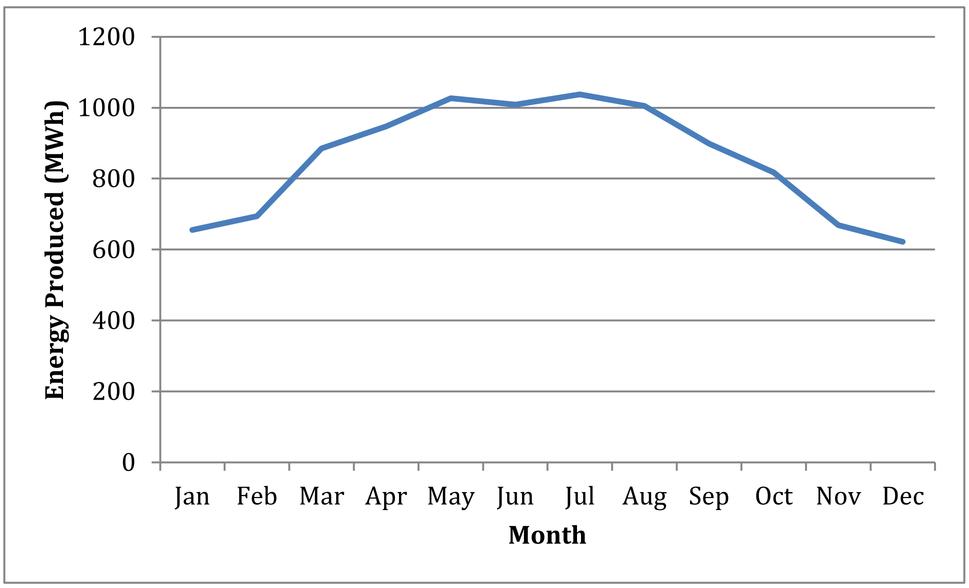

Figure 25: Amount of Energy that could be Produced Year Round with Solar Panels

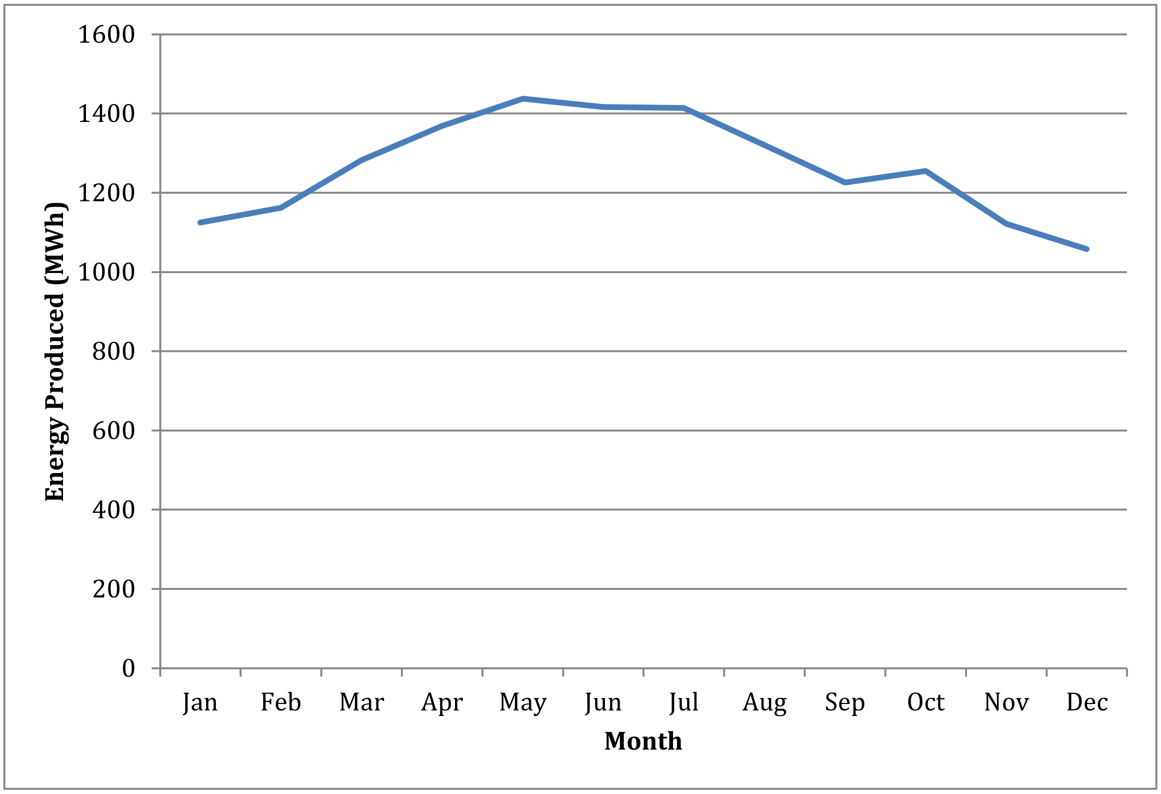

Figure 26: Combined Wind and Solar Energy

There is a gentle bell curve to the combined renewable energies in the graph above, peaking in the summer months of June July and August, but staying relatively constant throughout the year (See Figure 26). That there is a peak in summer will be beneficial in offsetting the peak energy use of Nantucket.

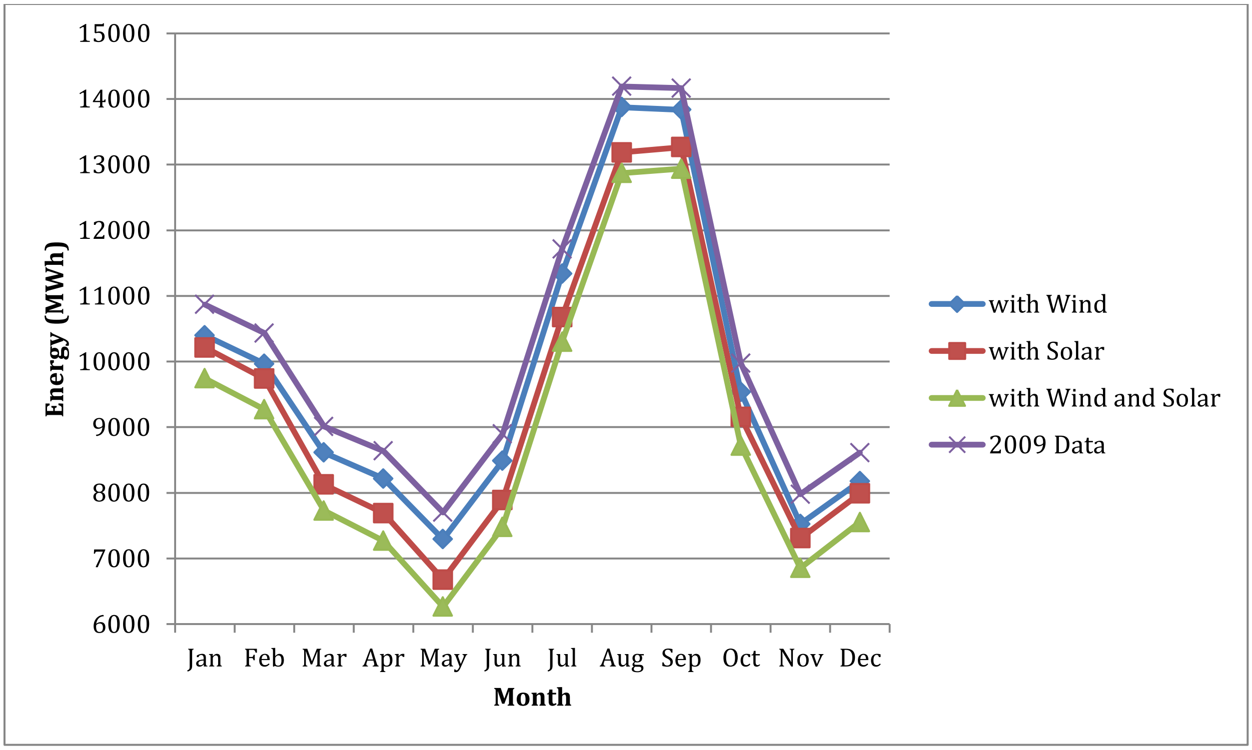

Figure 27: Reduction of 2009Aggregate Energy Consumption with Renewable Energy

Incorporation of solar and wind energy would shave off quite a bit of load on the cables to Nantucket, possibly postponing the need for a third cable even farther. As shown in Figure 32, renewable energy could play a significant role in reducing approximately 1000 MWh year round from the island's total energy use. This has a significant impact on the islands electricity usage and only accumulates to one wind turbine and four solar arrays worth of renewable generation sources. Therefore it may be beneficial for the island to consider more plans for renewable, since it can certainly play a role in delaying the need for more power capacity from the mainland.

Conservation Potential

In accordance with the islands tendency towards energy efficiency we also conducted studies on the conservation potential of the island. Conservation is generally recognized as the quickest way to bring electricity supply and demand into balance. Motivated consumers possess a variety of options to promptly reduce consumption, ranging from changing thermostat settings to becoming more vigilant in turning off lights. As a simpler method of saving money and electricity, conservation techniques can be applied to a wide variety of town systems and facilities in an effort to lower electricity use. Conservation is the process by which an organization implements new methodologies to limit the use of a scarce resource. In the case of Nantucket, there are many opportunities for changes to be made which could have a significant impact on the electricity usage of the town-owned facilities. Many of the recommendations made also apply to homeowners trying to reduce their electricity use.

The theory behind conservation of electricity is that both money and electricity can be saved by slightly changing habits and equipment, all while still continuing normal activities. Owners of facilities can financially save by purchasing less electricity each month. By incorporating different models of light bulbs or appliances you can vastly reduce how much electricity is consumed by your organization. Through this process, one-time system upgrades with an upfront cost will each have varying payback periods, each saving different amounts of money based on the technologies and upgrades. It is important to realize though, that all conservation techniques require some form of investment. Despite the initial capital necessary, many conservation projects can be funded, at least in part, by a variety of grants and rebates offered by the Federal and Massachusetts governments. The overall measured effect will be an immediate reduction in electricity consumption, immediately yielding a lower electric bill.

Methods of Conservation

Listed below (see Table 6) are the various methods by which organizations or individuals can conserve energy without interrupting their daily routines. Each method is briefly explained in terms of its difficulty to incorporate into daily life, the size of the initial investment, and the benefits the technology provides to consumers. The methods also are categorized as simplest to adopt, almost simple, labor intensive, and capital intensive. The metrics used to evaluate the diverse conservation tactics include the estimated percent reduction in cost, the estimated percent reduction in electric use, and the estimated payback period for your investment. Each scenario will be displayed together in a graph as to display the benefits of each one when compared to the remaining methods.

Current Technology	Conservation Technology
Incandescent Light Bulbs	Compact Fluorescent Bulbs
Plugged-in devices (vampire loads)	Unplugged devices
Set Thermostat	Programmable Thermostat
Leaky/inefficient HVAC	HVAC inspection (efficient)
Electric/Gas/Oil Heating & Cooling	Geothermal Heating & Cooling

Table 6: Current Technology vs. Conservation Methods

Simplest: Replace incandescent light bulbs with compact fluorescent lamp bulbs or LED lights

The movement away from incandescent light bulbs is largely thought of as a result of the inefficiencies of the early bulbs. When an incandescent bulb is lit, much of its electricity is converted to heat instead of the desired light. Compact Fluorescent Lamp bulbs are far more efficient, and produce limited waste and use far less electricity than original bulbs. Light Emitting Diode (LED) bulbs use even less electricity, and produce nearly no excess heat, making them a superior choice for consumers looking to save on electricity. Unfortunately, with new technologies comes more expenses, and CFL and LED bulbs are no exception. This doesn't mean though, that they are not economical, and an analysis of the payback periods of the bulbs show just how long it will be before the consumer begins to receive savings.

Assuming each CFL bulb has a cost of $3 each, a high estimate, and assuming the average life of a CFL to be 5-8 years, we can make estimates about the average savings in cost and electricity, as well as calculate the payback period for a consumer's investment in a new bulb. According to Energy Star, the US Department of Energy's conservation outreach sector, each CFL can save $71 or the equivalent of 450 kWh in its lifetime. Factoring in the cost of the bulb, and you receive a profit of $69 over the bulb's life, meaning your percent savings over the retail cost of the bulb is 2020% (Energy Star, 2009).

Energy Star estimates that the average payback period is 0.3 years, or three and half months, but this depends on how many hours each day the given bulb is used (Energy Star, 2009). Below is a graph that explains the payback periods of CFLs taking into account the number of hours each day that the bulb is used (see Figure 28). As it can be seen, the more that the bulb is used, the less time it takes to pay off the initial investment in the technology. If a bulb is used for 12 hours each day, it will only take about 18 days until you have recuperated your investment through your savings in electricity use, although this is variable based on electricity rates (Ghanta, 2010).

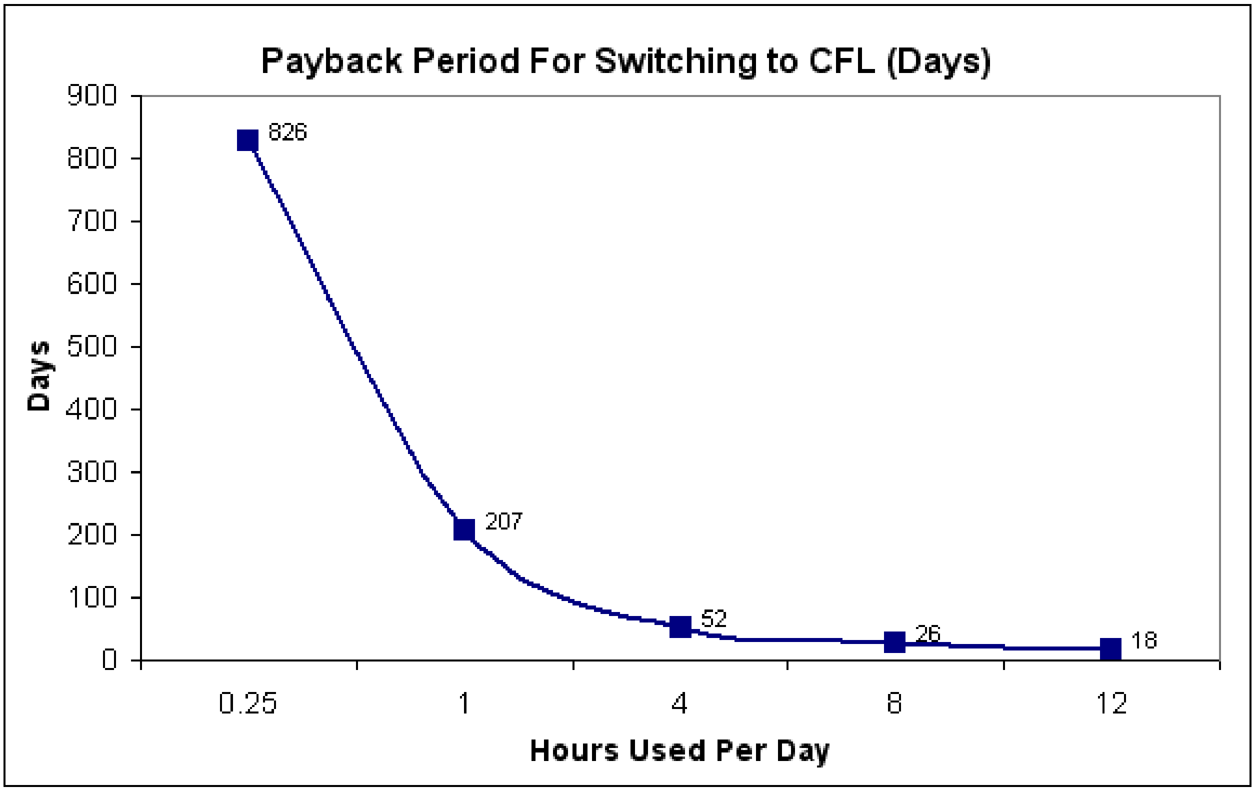

Figure 28: Payback Period for Switching to CFL (Days)
(Ghanta, 2010)

In terms of the effectiveness of CFL bulbs on Nantucket, we have applied the electricity use reduction percentages of installing the bulbs to the use in both the residential sector and the town office buildings. Our estimates are slightly high, since the reduction percentages call for converting nearly all light bulbs from incandescent to CFLs. In reality, some bulbs have most likely already been converted, or some bulbs simply cannot be switched due to incompatible fixtures. Our estimates of cost and use savings provide a maximum threshold for how much could potentially be saved through this conservation method. In our analysis of CFLs we applied a reduction of 7% of the total electric consumption if consumers installed compact fluorescent lamps widely in their homes (US Department of Energy, 2009a). We did not choose to represent LED bulb savings in our graphs, as we felt the cost of the bulbs compared to the benefits were too prohibitive to ensure the wide implementation of the technology at this time.

Simplest: Unplug All Unused Appliances

An easy way to save a significant amount of electricity is to unplug all appliances that are not in use at the moment. Most appliances and plugs will constantly draw "dead" electricity as long as they are connected to outlets. By being vigilant with plugs and outlets any building can reduce its electricity use by an average of 7.5 percent. As a method of conservation that requires no new investment, only a watchful eye, a significant reduction can be made. The payback on this tactic is instant, and savings are felt immediately (Grant & Morgan, 2010).

Almost Simple: Programmable Thermostats

The installation of a programmable thermostat is a method of conserving electricity through only using heating and cooling when necessary. The technology is relatively inexpensive, and requires no maintenance once it is installed and programmed. By programming the thermostat to automatically allow the heating or cooling to lower or raise the temperature during predetermined times when the consumer will not be home or sleeping. Typically the average cost of a single thermostat is $45, and they can be easily purchased at any hardware store. While the cost is slightly higher than replacing bulbs, the economics of the savings make it a worthwhile method of conservation (US Department of Energy 2009a).

The savings associated with installing a programmable thermostat appears excellent when compared to the cost and effort required to installing the unit. A programmable thermostat will save an average of 8% of the total electric use of the building, with the percentage yielding higher kWh savings in buildings that utilize both electric air conditioning as well as electric heat. The savings for an average homeowner are approximately $180 per year, meaning the payback period per thermostat is only three months. Further, there is no lifetime of a thermostat, so the savings felt after installing the system will be felt for many, many years with little to no maintenance (US Department of Energy 2009a).

Labor Intensive: HVAC Inspection

One major waster of electricity is a poorly functioning HVAC system. Systems that have leaks in the ducts release air that has been heated or cooled using electricity into spaces which the heating or cooling is not destined, requiring the central air system to produce more heated or cooled air. Further, ducts that are not properly insulated that pass through unheated or uncooled areas can lose a significant amount of their heated or cooled air to the heat differential between duct air and climate air. A leaky or inefficient HVAC system could be costing up to 20% in additional costs each month that could be saved by sealing all leaks and by insulating all ducts. To solve the problem, and to increase the efficiency of the system, an HVAC professional must be hired to conduct an inspection of the facility and all ducts. According to the US Department of

Energy, the average HVAC inspection will cost between $50 and $100 per building, depending on the size of the building. Normally this method would classify as fairly costly if inspections were conducted at all town buildings at once, but understanding the potential savings at each facility, the true cost is very limited. The potential savings suggest that this method of conservation should be seriously pursued (US Department of Energy, 2009a).

Capital Intensive: Transition to Geothermal Heating/Cooling of Buildings

Geothermal heating and cooling is considered a method of electricity conservation since the technology harnesses the natural temperature of the earth to either heat or cool water or air. The only electricity needed to operate the system is due to the pumps for water or fans to keeps air flowing. Geothermal heating and cooling has the potential to slash electric consumption, and can cut use by up to 30% (US Department of Energy, 2009a). It should be known however, that the cost of installing such a system could be prohibitive. The US Department of Energy estimates that the cost of installing a geothermal heat pump system could cost approximately $2,500 per ton of capacity, with a typical residential home needing 3 tons of capacity. With this estimate, it would be reasonable to say that the project could cost in the range of $7,500 per home. Since the costs are often viewed as too high, the upgrade is typically only completed in new construction, although more costly retrofits can be done. Though the investment in geothermal is among the most significant, the rewards of a significantly lower bill do make it a feasible option, and something that the Town of Nantucket should certainly consider for all new construction and significant renovations (US Department of Energy, 2009a).

Explanation of Savings for Nantucket

In order to predict what Nantucket could expect in terms of electric use and cost saving from rigorous conservation implementation, we applied the conservation estimates we gathered to the electric consumption data we obtained about the island as a whole, as well as to the town-owned buildings. We then identified what was easiest and most feasible to implement from our list of conservation methods. By creating a "simple conservation" category, composed of transitioning all light bulbs to CFLs, installing programmable thermostats, and by unplugging all unused appliances, we can more accurately represent what would most likely happen when Nantucket would implement any of the above methods of electricity conservation. To focus our application of the data and reductions, we first examined the potential electric savings the town buildings could achieve.

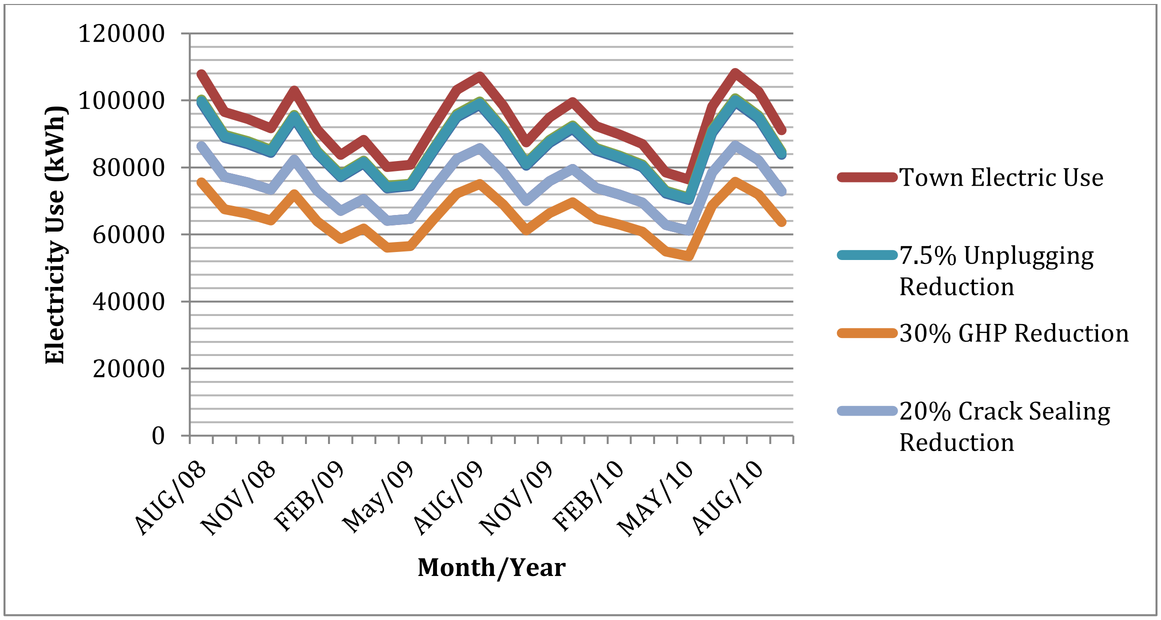

Figure 29: Potential Reductions in Electric Use for Nantucket Town Buildings

In the graph above (see Figure 29), it can be easily seen by how much each conservation method could reduce the town's current use independently of other conservation methods. This graph shows multiple lines, with the top red line being the current summation of the electric consumption of all town buildings. While the larger reductions have a greater impact on the use of electricity than the smaller reductions of other methods, this graph does not show the potential savings if two or more of these methods were combined.

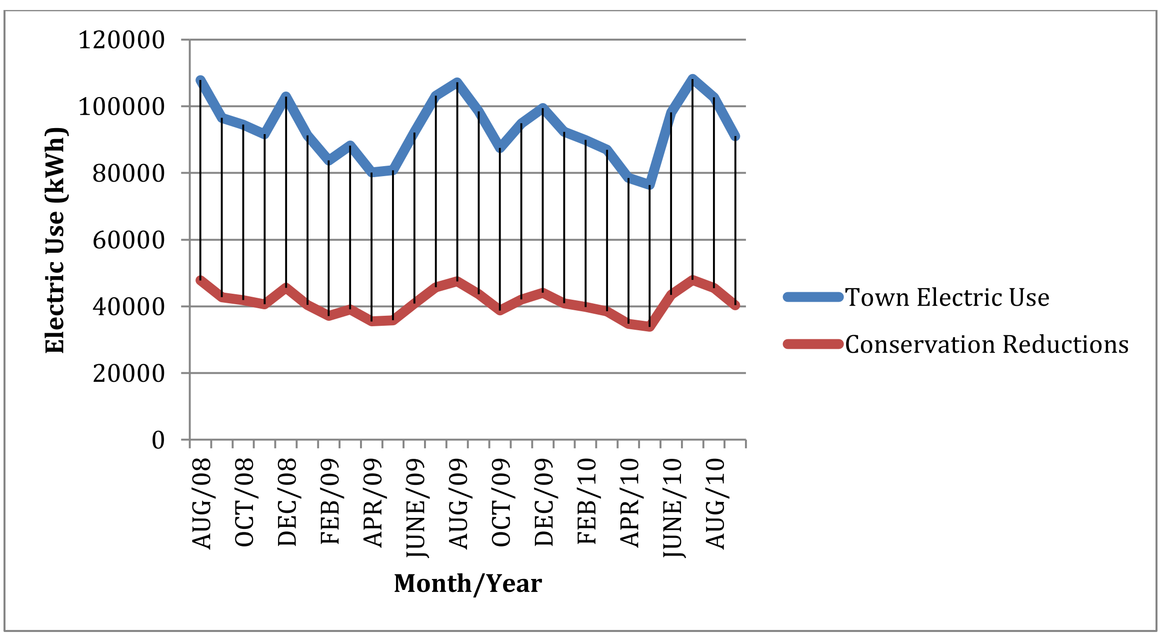

Figure 30: Total Electricity Reduction Potential for Nantucket Town Buildings

In Figure 30, the total reduction potential of the town buildings can be seen if the buildings were to incorporate all of the conservation methods identified in this report. Interestingly, the high peaks in the summer, which plague Nantucket's electric grid, are significantly reduced through the wide application of electricity conservation. Unfortunately, the cost of installing all potential methods identified in the report could be astronomical. It is important to understand the maximum savings that conservation could provide consumers, and this will provide a benchmark for other methods of cost and electricity savings.

In the graph below, our group introduces the "simple conservation" methods (see Figure 31). We chose to focus on three and analyze these methods more in-depth than previously in this section due to time constraints. The three methods that were chosen as simplest to install and maintain were the installation of programmable thermostats, the transition to CFL light bulbs, and the unplugging of all unused appliances. While the reductions are not as large as if the methods included one or more of the large reduction methods, the simple conservation methods are relatively inexpensive to install and maintain, and as shown in Figure 31, provide an approximate reduction of 20,000 kWh each month.

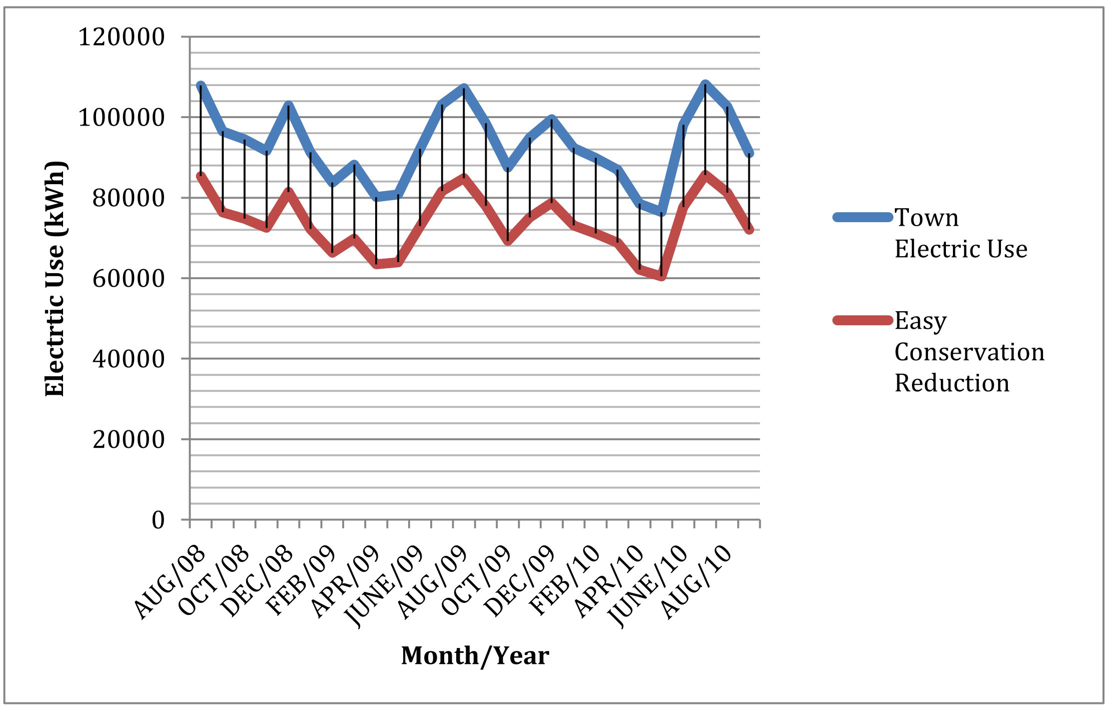

Figure 31: Island-Wide Conservation Savings

If you examine the potential savings of installing the simple conservation methods, the town has the opportunity save a sizeable amount of money each month on its electric bills.

Shown below is a graph of the potential reduction of the gross monthly electric bills for the Nantucket town offices (see Figure 32). The top line displays how much the town pays for electricity each month for the town office buildings, and the red line below displays how much the town could have paid if it had employed the simple conservation techniques outlined in this report. As shown in August 2010, the actual cost reaches a peak of nearly $24,000, while in the same month conservation would be $5,000 less at only $19,000 in the model that incorporates the simple conservation methods. This chart ultimately makes the argument that the town could be saving a significant amount of money each month that they employ basic conservation techniques.

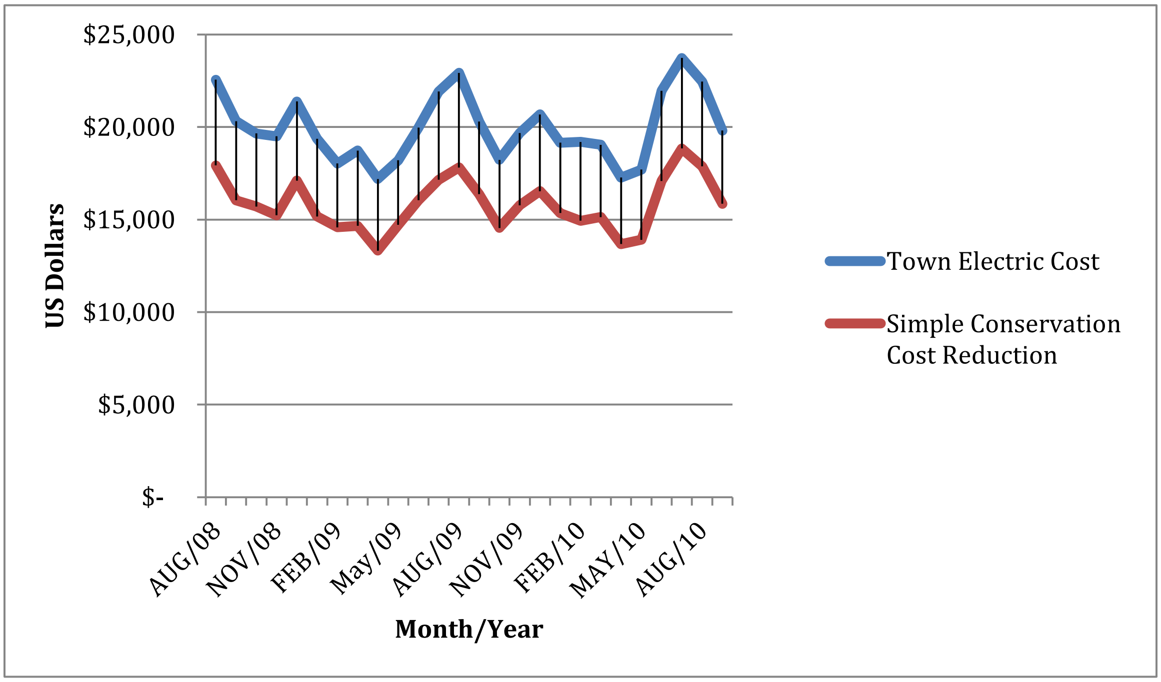

Figure 32: Potential Monthly Cost Savings of Conservation Techniques in Nantucket Town Office Buildings

If this model were to be summed, so that the gross savings over a single year was to be recorded, the amount of money saved in a given year would be astounding. Shown below in is a bar graph of the potential gross savings seen over a 12-month period after the incorporation of simple conservation methods (see Figure 33). As seen, the town of Nantucket could potentially save $53,000 per year if the town office buildings practiced the three simple conservations methods outlined in this report, assuming that none of these methods already been implemented.

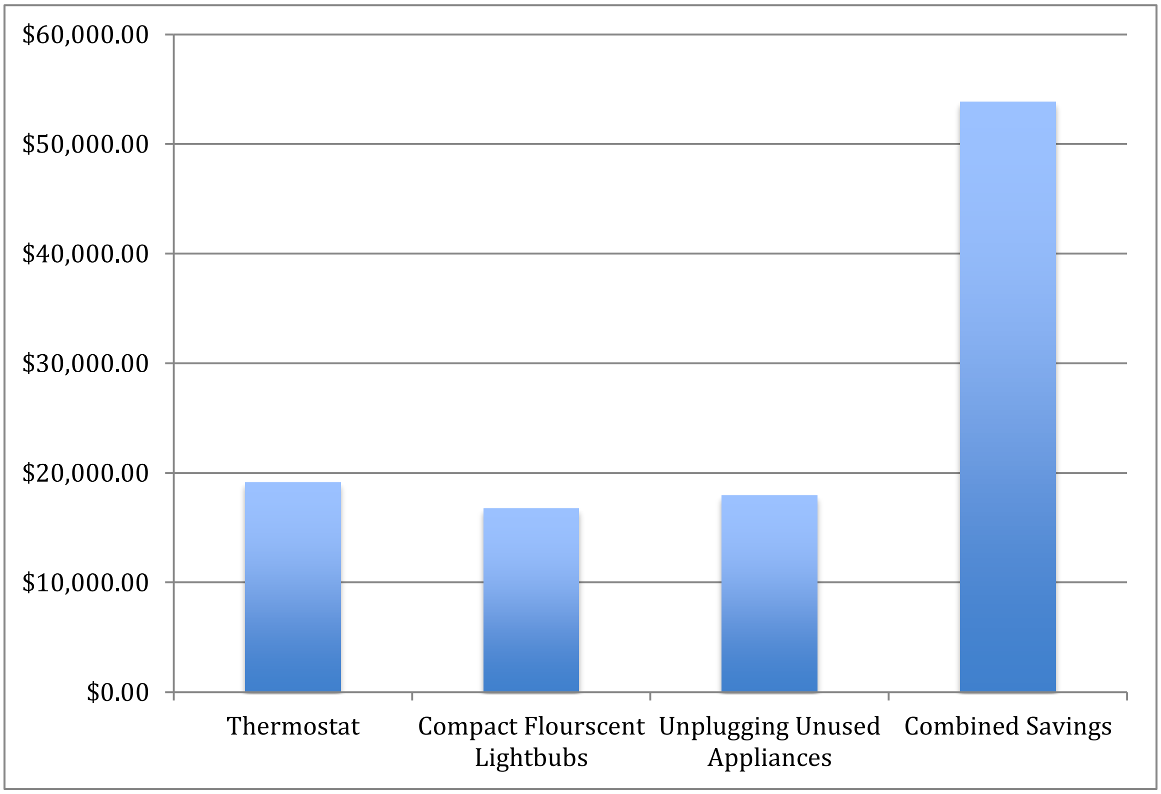

Figure 33: Gross Monetary Savings in Nantucket Town Buildings from Sept 09 - Aug 10

Ultimately conservation has the potential to save Nantucket significant amounts of electricity and money. When applied to the larger sectors of the island, such as the residential sector, the savings potential is incredible so long as there is widespread participation. Conservation on Nantucket also has the potential to offset to two potential increases with respect to the islands National Grid bills. If the island were able to begin to use less electricity through conservation methods, the higher summer rates could begin to fall and the installation of a third undersea cable could be delayed by years. The delaying of the installation of the cable would save ratepayers from a large spike in the cost of the cable surcharge that all National Grid account on Nantucket must pay each month.

Smart Grid

In order to delay the third submarine cable another option is available to Nantucket to facilitate electricity rate reduction. Smart grid studies have established the determinants of a flourishing smart grid are reliability, security, economics, power quality, efficiency and environmental quality and safety, all of which relate to Nantucket's grid (SAIC Smart Grid

Team, 2006; Miller, 2010). In our literature review of smart grid, we covered how smart grids deliver reliable, secure, efficient, safe energy to the end consumer. For our smart grid results we attempted to account for these components into the cost analysis on the basis that this would portray a successful smart grid by the SAIC Standards as well as NETL Standards.

Our cost-benefit analysis factors include an alternate rate structure, consumer information portal, smart appliances, voltage reduction, simple smart grid infrastructure costs and conservation tactics.

The rate structure we followed was from the current Xcel energy project in Boulder, Colorado. Their Smart Grid City has actuated a 90% outage reduction and a 5% reduction in electric demand to date (Accelerating Successful Smart Grid Pilots, 2010). If Colorado's success is an indication of Nantucket's potential and its reductions were applied to Nantucket, then Nantucket could reduce their average yearly usage by 154,946,993 kWh. This estimate is simply a quantitative reflection of a 5% reduction of the yearly electric consumption. Reductions can occur through a simple TOU rate but even greater reductions can occur with Peak Time Rebates, and can increase further with Peak Time Pricing (Miller, 2010)[7]. This reduction potential pivots around the communication between the customer and the utility.

Studies have shown that smart grids deployed with customer education methods in place return better results (Hughes, 2008). According to our literature review section on time-of-use rates there is a correlation between the number of portals through which customers can access their smart grid meter data and peak reduction. In accordance with this finding, we chose to include consumer portal reductions, assuming that Nantucket would optimize their smart grid with customer portals. Some of the communication techniques suggested includes emails, websites, bills (online or paper), phone calls, and in-home displays. This type of customer information system allows for communication of other enabling systems (e.g. smart meter data, rates, education, and demand response) (Miller, 2010).

Smart appliances are directly related to conservation techniques and an inevitable reduction in electric usage as devices break and a more efficient generation of appliances come to the consumer market. The customer information system coupled with smart appliance installation could be in the range of 5% reduction of overall electric usage (King, 2010).

[7] The table comparing exact reductions with the various rate scenarios are in Figure 8: Rate Structure Peak Reduction Comparison in the Literature Review of TOU rates

It is estimated that due to the optimized predictions of voltage for the utility through real-time demand data, there will be a reduction of 2.5%, attributable to enhanced efficiency (King, 2010). Although not a direct result of consumer decrease in usage, this reduction should be reflected in the consumer bills, since customers currently pay for over production. Therefore we calculated a further reduction of 2.5% in cost to consumers in our cost analysis.

Based on cost estimates provided by personal communication with Rick Hornby, a consultant at Synapse Energy Inc. we were able to simply sum up the initial capital costs of smart grids, based on per meter estimates. Cost per smart meter, as we learned, is the typical unit value applied to the many factors that are included in smart grid initial installations. According to Hornby's Testimony of 2009, the average cost per meter hovers around $220, which is the cost we used in our analysis.

As an addition to the above components to our smart grid, which are only applicable with full installation we also factored in simple conservation techniques. We wanted to create a scenario in which the island implemented a smart grid with the communication portal to inform consumers of reduction potential with simple tactics. We assumed that 5% of the island would engage in these cost savings, which is reflected in our analysis. The conservation aspect was covered in the previous section in depth, whereas the condensed version is reflected in the cost analysis.

We considered including renewable energy in our analysis but decided against that option because the renewable production capacity of residents is low[8]. Although we performed separate analysis on the potential savings of the current renewable, we did not include them is this analysis since they will only feed into the municipal buildings, not the island as a whole. Our cost analysis blankets the residential island population; therefore cost savings in the municipal sector will not grossly affect the residential.

Our smart grid scenario was only calculated for the residential meters on the island since the majority of savings that can be realized through smart grids are in residential homes (US Department of Energy, 2009b). Therefore by only installing them in the residential sector we hope to maximize possible savings, especially because of Nantucket's unique consumption profile with peaks residentially driven. The graph below is a summary of the findings with the

[8] Currently the cost vs. savings for the individual consumer buying renewable energy is not very appealing; therefore we predict that most of the future renewable will be larger projects funded by the town rather than the individual, especially in the coming 5 years, which is our payback time period.

estimated savings mentioned above (see Figure 34). The x-axis represents the percentage of the total meters in the residential sector we propose on replacing whereas the y-axis is the simple payback period of that installation. The constants in the calculation of this graph include the payback period of 5% implementation of simple conservation across the residential consumers, overall percentage reductions, TOU rate structure and the supply costs over time. The variables included meters installed and estimated peak reduction potential of that percentage of the population. As we can see, the payback period increases as the population of resident meters increases. The highest payback period with full implementation is 5.4 years at which level the residents would be saving in aggregate $500,000/year.

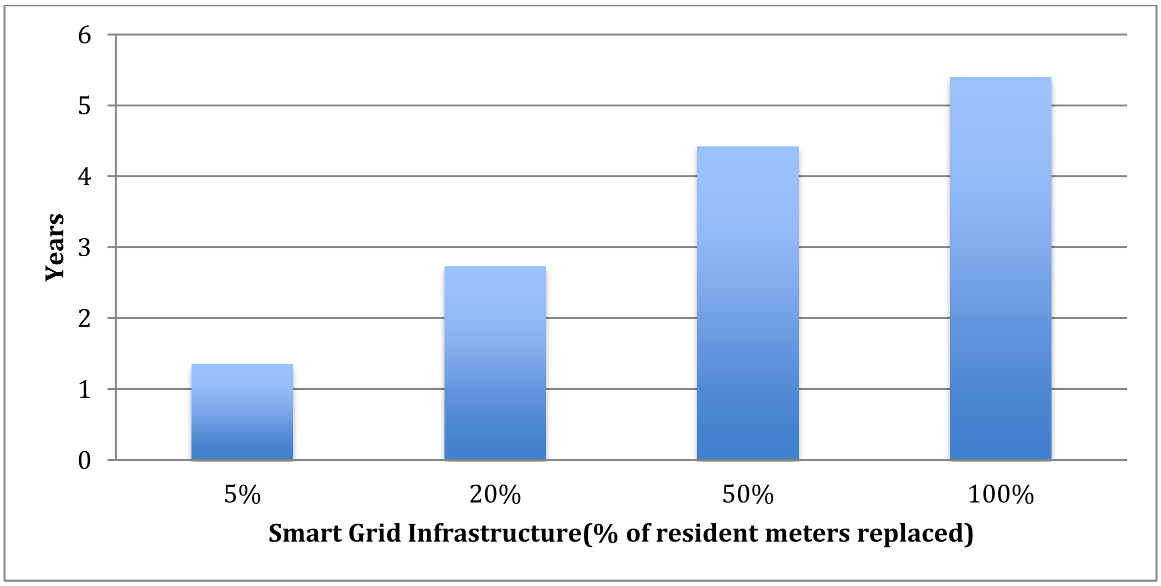

Figure 34: Simple Payback Period with Smart Grid & 5% Conservation Implementation

Too many variables are involved in future electric supply rates to accurately make a projection of rates in the years to come; therefore we calculated using supply rates for the island in 2009 for all years, underestimating the savings. The 2009 rate freeze point was also used to generate the graph below (see Figure 35). This Graph is an illustration of the yearly savings of the residential sector, at 100% installation, if it was able to reduce peaks by the percentage on the x-axis using TOU rates and AMI only. In this environment, consumers have more control over their power utilization.

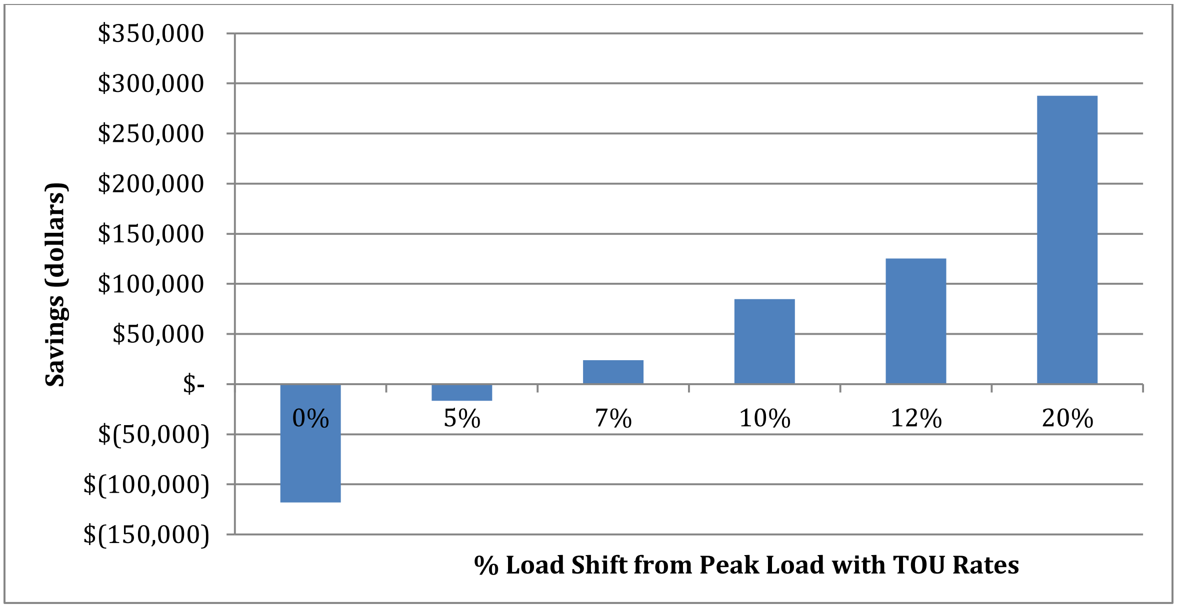

Figure 35: Sensitivity Graph of Yearly Savings from TOU and AMI Systems

Note: This graph was generated with a combination of (Xcel Energy, n.d.a; New Hampshire Electric Cooperative, Inc., 2009; Department of Energy Resources, 2001-2010). See Appendix 6: *Percentage Reduction Sources* for reasoning behind percentage load shifts.

In correlation with the peak reductions and cost, we also did a sensitivity analysis of the potential smart grids that would encourage peak power reduction, and therefore forestall a third submarine cable, by using less capacity in the current cables. The sensitivity graph, seen in Figure 36, of peak load reductions shows the possible reductions in power use and the corresponding delay in the 3rd cable installation to meet the flattened demand. (See Appendix 6 for the various calculations done for *Peak Power Reductions*).

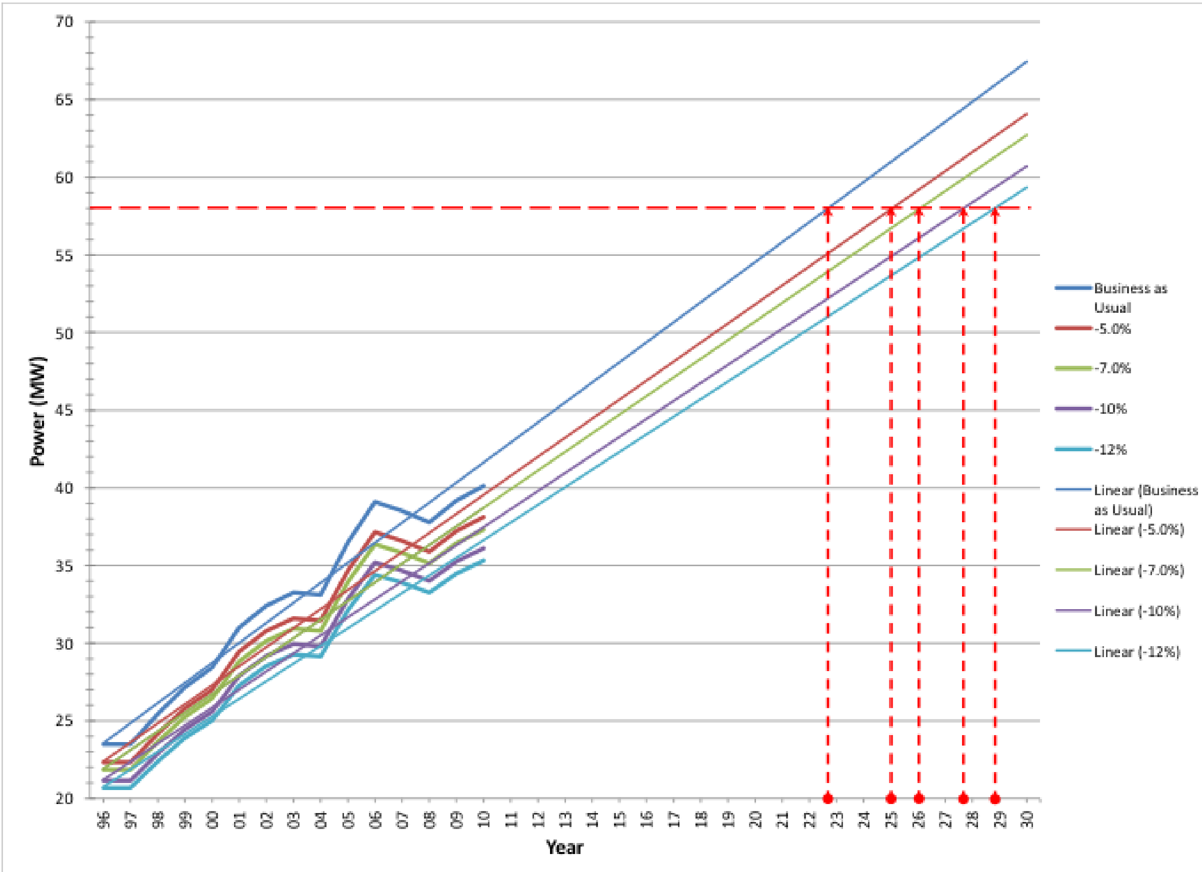

Figure 36: Sensitivity Graph of Peak Load Reductions

The graph above, Figure 36, illustrates how various levels of participation in a smart grid program, would delay the installation of a third cable. The larger the smart grid program is with willing participants, the more the third cable would be delayed. The sooner the cable is installed, the sooner a smart grid system would begin saving the island money based on the system. If 5, 7, 10 or12% of the peak was reduced through smart grid participation this is the result that would occur in relation to the third cable installation.

Below are four tables detailing the cost analysis scenarios (Table 7-10). Each contains the specific source for assumptions made. The graph demonstrating a 5% participation assumption refers to Table 7, which is the graph above on the yearly savings from TOU and AMI systems. This assumption was based on a conservative estimate of potential load reduction from the residential population. The conservation participant assumption was also based off of a conservative estimate of the potential followership a conservation program run through smart grid would experience.

Residential Sector 5%	Name	How To Figure		Value	Units
	Particpants (5%)	0.05*resident meters		564.95	meters
	Total kWh used	from Migration Report		83,448,693	kWh
	Business as Usual Cost	2009 rates*kWh	$	9,572,278	
1.Peak	Reduction	assumption		5%	
	TOU rates	1		0.12575	AVG ¢/kWh
	Savings	See Variable Rates Appendix	$	(827.66)	dollars
2. Energy Efficiency					
	Voltage reduction	2		0.025	
	Information + Better Appliances	3		0.05	
	Savings	cost*0.0375	$	17,979.06	dollars
3. Installation					
	Meter Cost	4		$220	dollars/meter
	Total Capital Investment	Meter Cost*meters		$124,289	dollars
4. Conservation	Participants	assumption		5%	
	Thermostat			8%	
	Unplugging			7.50%	
	CFL			7.00%	
	Savings	cost*0.208	$	99,373.32	dollars
	Cost	Avg. 3 month payback period	$	33,124.44	dollars
5. Cable Forestalled					
	Delay(0% peak reduction)	See Peak Reduction Appendix		0	months
Total Initial Cost			$	157,413.44	dollars
Total Revenue			$	116,524.72	dollars/year
Simple Payback				1.35	years

Citations
1 TOU rates: Summer On-peak(.221), Summer Off-peak (.087), Winter On-peak(.108), Winter Off-peak (.087)
2 Voltage Reduction:(King, 2010)
3 Information +Better Appliances: (King, 2010)
4 Meter Cost: (Hornby, 2009; King 2010)

Table 7: 5% Smart Grid Infrastructure Simple Payback Period

Residential Sector 20%	Name	How To Figure	Value	Units
	Particpants (20%)	0.02*resident meters	2259.8	meters
	Total kWh used	from Migration Report	83,448,693	kWh
	Business as Usual Cost	2009 rates*kWh	$ 9,572,278	
1.Peak	Reduction	assumption	12%	
	TOU rates	1	0.12575	AVG ¢/kWh
	Savings	See Variable Rates Appendix	$ 25,081.29	dollars
2. Energy Efficiency				
	Voltage reduction	2	0.025	
	Information + Better Appliances	3	0.05	
	Savings	cost*0.0375	$ 70,851.54	dollars
3. Installation				
	Meter Cost	4	$220	dollars/meter
	Total Capital Investment	Meter Cost*meters	$497,156	dollars
4. Conservation	Participants	assumption	5%	
	Thermostat		8%	
	Unplugging		7.50%	
	CFL		7.00%	
	Savings	cost*0.208	$ 98,553.99	dollars
	Cost	Avg. 3 month payback period	$ 32,851.33	dollars
5. Cable Forestalled				
	Delay(1% Peak Reduction)	See Peak Reduction Appendix	3	months
Total Initial Cost			$ 530,007.33	dollars
Total Revenue			$ 194,486.82	dollars/year
Simple Payback			2.73	years

Citations

1	TOU rates: Summer On-peak(.221), Summer Off-peak (.087), Winter On-peak(.108), Winter Off-peak (.087)
2	Voltage Reduction:(King, 2010)
3	Information +Better Appliances: (King, 2010)
4	Meter Cost: (Hornby, 2009; King 2010)

Table 8: 20% Smart Grid Infrastructure Simple Payback Period

Residential Sector 50%	Name	How To Figure	Value	Units
	Particpants (50%)	0.5*resident meters	5649.5	meters
	Total kWh used	from Migration Report	83,448,693	kWh
	Business as Usual Cost	2009 rates*kWh	$ 9,572,278	
1.Peak	Reduction	assumption	7%	
	TOU rates	1	0.12575	AVG ¢/kWh
	Savings	See Variable Rates Appendix	$ 12,003.33	dollars
2. Energy Efficiency				
	Voltage reduction	2	0.025	
	Information + Better Appliances	3	0.05	
	Savings	cost*0.0375	$ 179,030.09	dollars
3. Installation				
	Meter Cost	4	$220	dollars/meter
	Total Capital Investment	Meter Cost*meters	$1,242,890	dollars
4. Conservation	Participants	assumption	5%	
	Thermostat		8%	
	Unplugging		7.50%	
	CFL		7.00%	
	Savings	cost*0.208	$ 97,564.95	dollars
	Cost	Avg. 3 month payback period	$ 32,521.65	dollars
5. Cable Forestalled				
	Delay(7% Peak Reduction)	See Peak Reduction Appendix	4	years
Total Initial Cost			$ 1,275,411.65	dollars
Total Revenue			$ 288,598.37	dollars/year
Simple Payback			4.42	years

Citiations

1	TOU rates: Summer On-peak(.221), Summer Off-peak (.087), Winter On-peak(.108), Winter Off-peak (.087)
2	Voltage Reduction:(King, 2010)
3	Information +Better Appliances: (King, 2010)
4	Meter Cost: (Hornby, 2009; King 2010)

Table 9: 50% Smart Grid Infrastructure Simple Payback Period

Residential Sector 100%	Name	How To Figure		Value	Units
	Particpants (100%)	1*resident meters		11299	meters
	Total kWh used	from Migration Report		83,448,693	kWh
	Business as Usual Cost	2009 rates*kWh	$	9,572,278	
1.Peak	Reduction	assumption		7%	
	TOU rates	1		0.12575	AVG ¢/kWh
	Savings	See Variable Rates Appendix	$	12,003.33	dollars
2. Energy Efficiency					
	Voltage reduction	2		0.025	
	Information + Better Applianc	3		0.05	
	Savings	cost*0.0375	$	358,510.31	dollars
3. Installation					
	Meter Cost	4		$220	dollars/meter
	Total Capital Investment	Meter Cost*meters		$2,485,780	dollars
4. Conservation	Participants	assumption		5%	
	Thermostat			8%	
	Unplugging			7.50%	
	CFL			7.00%	
	Savings	cost*0.208	$	95,698.35	dollars
	Cost	Avg. 3 month payback period	$	31,899.45	dollars
5. Cable Forestalled					
	Delay(7% Peak Reduction)	See Peak Reduction Appendix		4	years
Total Initial Cost			$	2,517,679.45	dollars
Total Revenue			$	466,212.00	dollars/year
Simple Payback				5.40	years

Citiations	
1	TOU rates: Summer On-peak(.221), Summer Off-peak (.087), Winter On-peak(.108), Winter Off-peak (.087)
2	Voltage Reduction:(King, 2010)
3	Information +Better Appliances: (King, 2010)
4	Meter Cost: (Hornby, 2009; King 2010)

Table 10: 100% Smart Grid Infrastructure Simple Payback Period

Conclusions & Recommendations

The following will introduce the conclusions to the objectives of our project and recommendations the Smart Grid team has for the Energy Study Committee to proceed further. To review, our objectives were: (1) to evaluate the current energy profile and initiatives of Nantucket; (2) to analyze the effect of conservation efforts on Nantucket; (3) to project the effect of renewable energy on Nantucket; and (4) to identify the potential for smart grids and recommendations for Nantucket.

Objective 1: Current Energy Profile

The current yearly energy profile of Nantucket shows two consistently distinct peaks of energy per year; one in the summer and one in the winter. The higher of the two, always occurs during the summer month of August. The lower peak consistently may occur from the months December to February. August is continuously one of the most seasonally populated months on Nantucket Island, which accounts for the summer increase in electricity consumption. What is pushing the energy use up even more during the mid-summer month of August is the increasing use of air conditioning. According to our estimates of population based on solid municipal waste, the number of people on the island increases from approximately 11,500 people in the winter to 50,000 people in the summer.

The trends show an increasing electricity power peak each year. If this trend continues in a similar pattern without change, we project that a third cable must be installed by 2023. In 2023 the residents will still be paying the second cable surcharge, and may also begin paying off the $50-60 million capital cost of the third cable. Electricity rates would increase, patterns of electricity use would continue to rise and Nantucket will need to invest more in order to supply itself electricity. This leads into our next objectives, to decrease Nantucket's dependence on the utility supplied electric and achieve more economical electricity bills.

Objective 2: Effect of Conservation

Using the results and analysis the team obtained for the second objective, we compiled a series of conclusions and recommendations. By considering the calculated savings, with all capital costs included, a series of suggestions regarding various conservation techniques and programs were set forth for the town of Nantucket.

With respect to all conservation methods explored by the group, we recommend pursuing three conservation tools identified in the results and analysis of this report. After conducting a cost-benefit analysis of the initial cost of installation compared to the potential savings in both widespread and realistic applications of the techniques, we strongly recommend the adoption of compact fluorescent lights (CFL), programmable thermostats, and the practice of unplugging unused appliances in all homes and facilities. The minuscule payback periods, coupled with the low cost of installation and the negligible maintenance make these conservation methods unmatched in benefits it can provide the town.

Conservation requires time, work, lifestyle changes and initial costs. Converting all lights and thermostats in town owned facilities to the advanced models would require a significant amount of time and effort from the town's maintenance department. Regardless, the potential savings that would be felt by taxpayers, as outlined in our results and analysis section of this report, clearly point to the fact that the effort would reflect time well spent, and that the savings would be more than worth the time. Homeowners and business-owners are significant users as well, and should not be overlooked. The significant savings felt in town facilities, could also be reflected in homes and businesses across the island. The incorporation of simple conservation into all sectors of Nantucket should be a top priority moving forward.

In order to achieve widespread success in any conservation measures there must be a significant public outreach campaign. This targeted campaign could easily take into account town buildings, residential homes, and businesses as key focus areas for reductions in electric use. Public outreach on Nantucket would be necessary in large part because conservation efforts are alterations in behavioral patterns. By educating the Nantucket populous about the need to reduce electric consumption, and the options available, the electric consumers on the island can better choose to reduce use. Unless consumers on Nantucket are made explicitly aware of the push for electric conservation, it is not feasible to expect significant reductions.

The creation of conservation programs, to be organized under the direction of the Nantucket Energy Study Committee should be a primary goal for the Town of Nantucket to pursue. Key areas for significant conservation impact include the summer vacationer population, a demographic that can use electricity without regard to its greater implications. As individuals' on-island temporarily, this group should be educated through strategic partnerships with key hotels, inns, and rental businesses. Our group strongly recommends the creation and adoption of an educational plan to raise awareness of conservation techniques, and to ultimately drive increased participation in electricity conservation as to reduce the use of electricity on Nantucket.

Objective 3: Project Renewable Energy

Installing more renewable energy on the island of Nantucket could reduce the amount of electricity needed from the mainland. However renewable energy, such as wind and solar, always face the issue of erratic generation due to variances in the sun or wind. While we agree renewable energy would be beneficial to reduce the island's dependence on the two submarine cables, it is not reliable enough to depend on postponing installation of the third cable. This is because if there were a spike in energy use, and it did not happen to be a calm cloudy day, the wind turbines or the solar arrays could produce the necessary electricity. However, through our findings we have concluded that the energy produced by the proposed wind turbines and solar arrays would be beneficial combination. The two would complement each other well creating a constant amount of energy, averaging 1,200 kWh per month. There would be slightly more electricity produced in the summer, which would complement the summer's higher energy demand very well.

Objective 4: Identify Potential for Smart Grid

Smart grid uses four main technologies: advanced metering infrastructure, customer information systems, demand response, and distributed energy management. Through these technologies they provide reliable service, bill savings, information, electricity management and optional generation selling power to the residential consumers.

Electricity usage reductions do not occur from just a smart grid infrastructure though; the pivotal goal of smart grid consumer communication is adoption (D. Hurley, personal communication, 2010). The early adopters will lead the transition from ignorant electric usage to 'smart' usage. The power to reduce is left in the hands of the consumer, but the consumer must be educated in order to wield their power. Smart grid can be the tool that will provide the information but an initial education must first be instituted on the island. This education begins with meetings, question and answer sessions, and a general awareness program.

The implementation process begins with negotiations with the utility company. The utility company, National Grid, owns the grid therefore without their cooperation a smart grid is unattainable. Demand response programs, which include time of use rates, play a large role during negotiations and public perception. If peak rates are high and off-peak is very low the likelihood increases that peak demands will be reduced because consumers will recognize the monetary incentives.

The cost of the smart grid is passed to the consumer population through the time of use rates, funded directly by grant money from the federal government, or the utility takes on all costs if it is a pilot and may be reimbursed in part by the government. Smart grids are rarely ever funded privately or by the town because the most incentives for smart grid still lie with the utility (D. Hurley & R. Tullman, personal communication, 2010).

We found with our cost-benefit analysis the simple payback periods for certain percentages of residential consumers to install smart grids. Installing 5%, 20%, 50%, 100% smart grid infrastructure over the entire residential population has a payback period of 1.35, 2.73, 4.42 and 5.4 years respectively. A smart meter costs in the range of $220-$600; certain demand response programs can reduce peak electric usage by 10% as well as overall usage.

We recommend that Nantucket further explore the option of smart grid through contacting National Grid and proposing this new technology for the future if these payback periods are truly indicative of the costs the island would experience. If National Grid is interested in pursuing a smart grid on Nantucket, negotiations may begin. A third party, with expertise in smart grid systems, may need to be included in negotiating a rate structure with National Grid to make sure the town receives a reasonable rate agreement.

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Appendix 1: List of Acronyms

- **AC:** Alternating Current or Air Conditioner(s)
- **AMI:** Advanced Metering Infrastructure
- **CFL:** Compact Fluorescent Lamp(s)
- **DC:** Direct Current
- **DOE:** Department of Energy
- **DOER:** Department of Energy Resources
- **DPW:** Department of Public Works
- **E.U.:** European Union
- **EMD:** Electro Motive Diesel
- **G-1**: Small Commercial and Industrial Electric User (National Grid Term)
- **G-2**: Medium Commercial and Industrial Electric User (National Grid Term)
- **G-3:** Large Commercial and Industrial Electric User
- **GE:** General Electric
- **GHG:** Greenhouse Gas
- **HVAC:** Heating, Ventilating, and Air Conditioning
- **IQP:** Interactive Qualifying Project
- **kW:** Kilowatt
- **kWh:** Kilowatt Hour
- **LED:** Light Emitting Diode
- **MW:** Megawatt
- **MWh:** Megawatt Hour
- **n.d.:** no date
- **NESC:** Nantucket Energy Study Committee
- **NETL:** National Energy Technology Laboratory
- **NIST:** National Institute of Standards and Technologies
- **NRTA**: Nantucket Regional Transit Authority
- **OEN:** Optimized Energy Networks
- **R-1**: Non-Low Income Residential Electric User (National Grid Term)
- **R-2**: Low Income Residential Electric User (National Grid Term)
- **R-4**: Time-of-Use Residential Electric User (National Grid Term)
- **S-1:** Street Lighting Service (National Grid Term)
- **SREC:** Solar Renewable Energy Credits
- **TOU:** Time-of-Use
- **W:** Watt
- **WEF:** Word Economic Forum

Appendix 2: Glossary

- **Advanced Metering Infrastructure (AMI):** When electric meters are used to automatically record the energy consumption, and report it to the utility company at regular intervals.
- **Capital Cost:** The combined cost of field development, plant construction, and the necessary equipment for industry operations.
- **Congestion:** Occurs in when there is not enough energy in the transmission lines to meet the demands of all end users.
- **Distributed Generator:** A generator that has a location near a particular load that it is intended to assist.
- **Distribution:** The ability to deliver energy to the end user.
- **Distribution System:** The part of the transmission and facilities processes that is focused in delivering the electric energy to its end user.
- **Electric Power:** The rate at which energy is transferred, and is typically measured in megawatts (MW)
- **Electricity Demand:** The rate at which the energy is transferred to each end user through the generation, transmission and distribution processes.
- **Fuel Cell:** A device that is able to convert a chemical fuel directly into electricity, and the active fuel material are not contained in the cells and are provided from outside of the cells.
- **Generation:** Producing electricity through transforming other forms of energy.
- **Global Warming:** When the surface of the atmosphere experiences an increase in temperature through the emissions of greenhouse gases.
- **Greenhouse Gas (GHG):** Gases such as carbon dioxide, nitrous oxide, methane, and sulfur hexafluoride and creates a radiation which decreases the Earth's protective atmosphere.
- **Load:** The amount of electricity either delivered or needed at any specific place on the electric grid.
- **Off-Peak:** A time when the demand of the grid is low and typically occur in a daily and seasonal patterns.
- **On-Peak:** A time when the demand of the electric grid is high, and typically occur in a daily and seasonal patterns.
- **Outage:** A time when there is a failure in the power generating facility or the high powered transmission lines.
- **Peak Load:** The maximum amount of power required to supply customers at any given time, including the time when the needs are the greatest.
- **Power Plant:** An industrial facility use for the production of electricity.
- **Rate Base:** Used as a base value for determining the amount a utility company may be permitted to earn based on the property value a current utility owns.
- **Solar Energy:** The radiant energy from the sun that is converted into electricity.
- **Time-of-Use:** rates that are based on specific time periods, where there may be different rates for a summer peak, summer off-peak and non-summer periods (Hornby, 2009).
- **Transmission:** Large capacity lines that have the capability to transfer large amounts of electricity from the power generating facilities to various substations.
- **Wind Energy:** When the kinetic energy from wind is able to be converted into mechanical energy in order to generate electricity.

Appendix 3: Energy Consumption Data requested from National Grid

Objective of questions: To ascertain the electric consumption rates to the smallest degree that National Grid tracks for the Island of Nantucket to be able compare the consumption rates and costs per sector before and after a hypothetical smart grid installation on the island.

1. Are the following the only sectors National Grid has data for on Nantucket?
    a. R1 (residential)
    b. R2
    c. R4
    d. E
    e. G1 (under 10,000 kW)
    f. G2 (over 10,000 kW)
    g. G3 (Industrial users)
    h. S1 (streetlights)
    i. S2
    j. S3
    k. S20
2. Have the rates been updated since the 2009 National Grid Summary of Rates for Nantucket?
    a. If so could we have a copy of the 2010 National Grid Summary of Rates for Nantucket?
    b. Could we have a copy of the summary of rates for the past 5 years?
3. Overall energy consumption per sector and the island as a whole?
    a. Hourly, daily, monthly, and/or seasonal usage averages (the smallest breakdown possible that is available)
    b. Could we have this data from the past 5 years?
4. Could we have information on the overall energy supply to the island? (i.e. on October 14th 27 MWh were generated and sent to the island over transmission line 1)
    a. Hourly, daily, monthly, and/or seasonal usage averages (the smallest breakdown possible that is available)
    b. Could we have this data from the past 5 years?

5. How many consumers are in each sector?
6. Could we have a copy of the power distribution grid map on Nantucket?
7. Is there an average size or distribution of sizes (square footage) of individual dwellings and apartments (R1) and kWh usage per unit of time associated with each size?
    a. Are there any R4 customers on the Island of Nantucket?
        i. Is it possible for customers under the 2,500 kWh per month usage cut off in the R4 sector to choose to be charged based on an on or off-peak rate?
8. What the plans are for cape wind project routing transmission lines to Nantucket, and how this would affect the users of each section in terms of rates?
9. Is the amount of energy grid waste significant enough to impact rates to the different users on the island?
10. Is there a possibility we could have a list the specific G3 users, given that there are not that many on Nantucket Island?
11. Which energy sectors do the municipality buildings on Nantucket fall into? How many municipality buildings are there on the island? Or are these buildings not separated from the general customers on the island?

Appendix 4: Aggregate Data from the Electric Migration Reports (Department of Energy Resources, 2001-2010)

	Month & Year (2006)	Jan '06	Feb '06	Mar '06	Apr '06	May '06	Jun '06	Jul '06	Aug '06	Sep '06	Oct '06	Nov '06	Dec '06
kWh Used by Basic Service Customers for Month (b)	Residential-- Non Low Income	8,488,847	6,581,914	7,686,854	6,177,316	5,721,404	6,368,589	8,251,900	11,087,842	9,948,444	6,640,251	5,922,081	6,941,957
	Residential -- Low Income	109,814	97,422	128,704	96,018	81,424	75,979	72,568	77,597	75,781	68,647	71,996	90,003
	Residential -- Time-of-Use	0	0	0	0	0	0	0	0	0	0	0	0
	Small Commercial & Industrial	1,806,036	1,311,911	1,474,418	1,393,877	1,416,117	1,821,918	2,159,960	2,857,292	2,736,258	2,114,156	1,517,172	1,537,765
	Medium Commercial & Industrial	879,419	642,174	677,169	584,948	591,684	788,422	873,571	2,375,857	1,030,781	956,917	390,004	814,542
	Large Commercial & Industrial	342,260	303,860	297,940	325,400	296,400	329,680	439,160	234,700	215,140	213,920	181,480	212,180
	Farms	0	0	0	0	0	0	0	0	0	0	0	0
	Street Lights	2,033	1,730	1,809	1,440	-729	1,105	993	532	473	8,625	6,079	-13,791
	Total Sales to Ultimate Consumers	11,628,409	8,939,011	10,266,894	8,578,999	8,106,300	9,385,693	11,798,152	16,633,820	14,006,877	10,002,516	8,088,812	9,582,656

	Month & Year (2007)	Jan '07	Feb '07	Mar '07	Apr '07	May '07	Jun '07	Jul '07	Aug '07	Sep '07	Oct '07	Nov '07	Dec '07
kWh Used by Basic Service Customers for Month (b)	Residential-- Non Low Income	7,783,493	7,751,887	8,103,725	6,724,716	6,032,393	6,425,581	7,998,944	10,969,204	10,585,963	6,868,949	5,970,249	7,967,273
	Residential -- Low Income	113,928	100,383	108,897	91,275	73,144	81,292	62,848	68,383	69,560	57,696	59,245	87,370
	Residential -- Time-of-Use	0	0	0	0	0	0	0	0	0	0	0	0
	Small Commercial & Industrial	1,715,381	1,588,802	1,477,969	1,400,228	1,435,163	1,708,924	1,975,167	2,646,173	2,781,805	1,979,718	1,588,112	1,774,030
	Medium Commercial & Industrial	471,283	415,513	402,533	438,154	531,759	548,349	633,498	745,630	765,154	540,767	527,031	560,749
	Large Commercial & Industrial	201,300	161,715	150,180	149,960	183,740	135,680	138,080	151,840	0	0	0	0
	Farms	0	0	0	0	0	0	0	0	0	0	0	0
	Street Lights	418	26,496	48,682	5,976	5,269	5,281	4,869	5,069	6,476	6,688	7,565	8,972
	Total Sales to Ultimate Consumers	10,285,803	10,044,796	10,291,986	8,810,309	8,261,468	8,905,107	10,813,406	14,586,299	14,208,958	9,453,818	8,152,202	10,398,394

	Month & Year (2008)	Jan '08	Feb '08	Mar '08	Apr '08	May '08	Jun '08	Jul '08	Aug '08	Sep '08	Oct '08	Nov '08	Dec '08
kWh Used by Basic Service Customers for Month (b)	Residential-- Non Low Income	8,669,686	7,555,419	6,874,356	6,607,851	5,536,287	6,528,167	9,073,467	11,924,791	10,313,512	6,748,775	6,190,011	7,356,121
	Residential -- Low Income	101,844	98,912	97,859	86,867	72,979	70,543	68,071	72,192	63,253	51,282	75,734	108,879
	Residential -- Time-of-Use	0	0	0	0	0	0	0	0	0	0	0	0
	Small Commercial & Industrial	1,736,478	1,486,081	1,389,213	1,392,131	1,323,245	1,613,081	2,128,755	2,802,380	2,605,320	1,899,371	1,596,385	1,501,921
	Medium Commercial & Industrial	503,199	580,028	464,797	714,379	590,546	693,562	769,148	946,974	872,963	735,165	818,963	704,343
	Large Commercial & Industrial	0	0	0	0	0	0	0	0	0	126,880	152,960	124,160
	Farms	0	0	0	0	0	0	0	0	0	0	0	0
	Street Lights	9,846	7,227	7,195	6,009	5,298	5,019	5,488	5,312	6,717	7,172	7,643	8,890
	Total Sales to Ultimate Consumers	11,021,053	9,727,667	8,833,420	8,807,237	7,528,355	8,910,372	12,044,929	15,751,649	13,861,765	9,568,645	8,841,696	9,804,314

	Month & Year (2009)	Jan '09	Feb '09	Mar '09	Apr '09	May '09	Jun '09	Jul '09	Aug '09	Sep '09	Oct '09	Nov '09	Dec '09
kWh Used by Basic Service Customers for Month (b)	Residential-- Non Low Income	8,130,017	7,743,458	6,645,552	6,196,766	5,391,832	6,172,715	8,425,869	10,574,288	10,331,559	6,972,495	5,677,593	6,408,962
	Residential -- Low Income	127,296	134,847	123,399	126,603	98,723	92,624	99,812	95,913	100,951	91,263	95,118	94,174
	Residential -- Time-of-Use	0	0	0	0	0	0	0	0	0	0	0	0
	Small Commercial & Industrial	1,560,336	1,529,615	1,381,760	1,299,943	1,256,965	1,467,773	2,028,356	2,338,689	2,390,620	1,807,838	1,432,281	1,405,487
	Medium Commercial & Industrial	760,812	781,456	620,443	736,094	702,959	844,795	849,850	868,654	1,001,814	819,356	637,915	556,340
	Large Commercial & Industrial	280,600	235,560	233,960	272,280	248,600	313,400	305,960	307,480	331,600	276,800	127,600	138,000
	Farms	0	0	0	0	0	0	0	0	0	0	0	0
	Street Lights	8,912	8,092	6,974	6,183	5,072	5,495	5,001	5,144	6,937	6,943	7,597	8,814
	Total Sales to Ultimate Consumers	10,867,973	10,433,028	9,012,088	8,637,869	7,704,151	8,896,802	11,714,848	14,190,168	14,163,481	9,974,695	7,978,104	8,611,777

	Month & Year (2010)	Jan '10	Feb '10	Mar '10	Apr '10	May '10	Jun '10	Jul '10	Aug '10
kWh Used by Basic Service Customers for Month (b)	Residential-- Non Low Income	8,390,418	7,432,987	6,582,430	5,593,452	6495696	6,615,006	9,795,770	12,332,755
	Residential -- Low Income	163,411	147,137	130,654	112,666	112414	97,857	113,203	116,338
	Residential -- Time-of-Use	0	0	0	0	0	0	0	0
	Small Commercial & Industrial	1,679,456	1,544,046	1,453,946	1,370,910	1429716.5	1,522,348	2,091,293	2,629,880
	Medium Commercial & Industrial	712,825	551,308	530,432	501,858	543386	738,389	1,006,720	1,098,371
	Large Commercial & Industrial	131,800	122,400	132,800	128,200	135400	149,600	163,200	168,000
	Farms	0	0	0	0	0	0	0	0
	Street Lights	9,371	7,458	6,905	6,513	7859.5	5,087	5,283	5,508
	Total Sales to Ultimate Consumers	11,087,281	9,805,336	8,837,167	7,713,599	8724472	9,128,287	13,175,469	16,350,852

	Month & Year (2006)	Jan '06	Feb '06	Mar '06	Apr '06	May '06	Jun '06	Jul '06	Aug '06	Sep '06	Oct '06	Nov '06	Dec '06
kWh Used by Basic Service Customers for Month (b)	Residential-- Non Low Income	8,488,847	6,581,914	7,686,854	6,177,316	5,721,404	6,368,589	8,251,900	11,087,842	9,948,444	6,640,251	5,922,081	6,941,957
	Residential -- Low Income	109,814	97,422	128,704	96,018	81,424	75,979	72,568	77,597	75,781	68,647	71,996	90,003
	Residential -- Time-of-Use	0	0	0	0	0	0	0	0	0	0	0	0
	Small Commercial & Industrial	1,806,036	1,311,911	1,474,418	1,393,877	1,416,117	1,821,918	2,159,960	2,857,292	2,736,258	2,114,156	1,517,172	1,537,765
	Medium Commercial & Industrial	879,419	642,174	677,169	584,948	591,684	788,422	873,571	2,375,857	1,030,781	956,917	390,004	814,542
	Large Commercial & Industrial	342,260	303,860	297,940	325,400	296,400	329,680	439,160	234,700	215,140	213,920	181,480	212,180
	Farms	0	0	0	0	0	0	0	0	0	0	0	0
	Street Lights	2,033	1,730	1,809	1,440	-729	1,105	993	532	473	8,625	6,079	-13,791
	Total Sales to Ultimate Consumers	11,628,409	8,939,011	10,266,894	8,578,999	8,106,300	9,385,693	11,798,152	16,633,820	14,006,877	10,002,516	8,088,812	9,582,656

	Month & Year (2007)	Jan '07	Feb '07	Mar '07	Apr '07	May '07	Jun '07	Jul '07	Aug '07	Sep '07	Oct '07	Nov '07	Dec '07
kWh Used by Basic Service Customers for Month (b)	Residential-- Non Low Income	7,783,493	7,751,887	8,103,725	6,724,716	6,032,393	6,425,581	7,998,944	10,969,204	10,585,963	6,868,949	5,970,249	7,967,273
	Residential -- Low Income	113,928	100,383	108,897	91,275	73,144	81,292	62,848	68,383	69,560	57,696	59,245	87,370
	Residential -- Time-of-Use	0	0	0	0	0	0	0	0	0	0	0	0
	Small Commercial & Industrial	1,715,381	1,588,802	1,477,969	1,400,228	1,435,163	1,708,924	1,975,167	2,646,173	2,781,805	1,979,718	1,588,112	1,774,030
	Medium Commercial & Industrial	471,283	415,513	402,533	438,154	531,759	548,349	633,498	745,630	765,154	540,767	527,031	560,749
	Large Commercial & Industrial	201,300	161,715	150,180	149,960	183,740	135,680	138,080	151,840	0	0	0	0
	Farms	0	0	0	0	0	0	0	0	0	0	0	0
	Street Lights	418	26,496	48,682	5,976	5,269	5,281	4,869	5,069	6,476	6,688	7,565	8,972
	Total Sales to Ultimate Consumers	10,285,803	10,044,796	10,291,986	8,810,309	8,261,468	8,905,107	10,813,406	14,586,299	14,208,958	9,453,818	8,152,202	10,398,394

	Month & Year (2008)	Jan '08	Feb '08	Mar '08	Apr '08	May '08	Jun '08	Jul '08	Aug '08	Sep '08	Oct '08	Nov '08	Dec '08
kWh Used by Basic Service Customers for Month (b)	Residential-- Non Low Income	8,669,686	7,555,419	6,874,356	6,607,851	5,536,287	6,528,167	9,073,467	11,924,791	10,313,512	6,748,775	6,190,011	7,356,121
	Residential -- Low Income	101,844	98,912	97,859	86,867	72,979	70,543	68,071	72,192	63,253	51,282	75,734	108,879
	Residential -- Time-of-Use	0	0	0	0	0	0	0	0	0	0	0	0
	Small Commercial & Industrial	1,736,478	1,486,081	1,389,213	1,392,131	1,323,245	1,613,081	2,128,755	2,802,380	2,605,320	1,899,371	1,596,385	1,501,921
	Medium Commercial & Industrial	503,199	580,028	464,797	714,379	590,546	693,562	769,148	946,974	872,963	735,165	818,963	704,343
	Large Commercial & Industrial	0	0	0	0	0	0	0	0	0	126,880	152,960	124,160
	Farms	0	0	0	0	0	0	0	0	0	0	0	0
	Street Lights	9,846	7,227	7,195	6,009	5,298	5,019	5,488	5,312	6,717	7,172	7,643	8,890
	Total Sales to Ultimate Consumers	11,021,053	9,727,667	8,833,420	8,807,237	7,528,355	8,910,372	12,044,929	15,751,649	13,861,765	9,568,645	8,841,696	9,804,314

	Month & Year (2009)	Jan '09	Feb '09	Mar '09	Apr '09	May '09	Jun '09	Jul '09	Aug '09	Sep '09	Oct '09	Nov '09	Dec '09
kWh Used by Basic Service Customers for Month (b)	Residential-- Non Low Income	8,130,017	7,743,458	6,645,552	6,196,766	5,391,832	6,172,715	8,425,869	10,574,288	10,331,559	6,972,495	5,677,593	6,408,962
	Residential -- Low Income	127,296	134,847	123,399	126,603	98,723	92,624	99,812	95,913	100,951	91,263	95,118	94,174
	Residential -- Time-of-Use	0	0	0	0	0	0	0	0	0	0	0	0
	Small Commercial & Industrial	1,560,336	1,529,615	1,381,760	1,299,943	1,256,965	1,467,773	2,028,356	2,338,689	2,390,620	1,807,838	1,432,281	1,405,487
	Medium Commercial & Industrial	760,812	781,456	620,443	736,094	702,959	844,795	849,850	868,654	1,001,814	819,356	637,915	556,340
	Large Commercial & Industrial	280,600	235,560	233,960	272,280	248,600	313,400	305,960	307,480	331,600	276,800	127,600	138,000
	Farms	0	0	0	0	0	0	0	0	0	0	0	0
	Street Lights	8,912	8,092	6,974	6,183	5,072	5,495	5,001	5,144	6,937	6,943	7,597	8,814
	Total Sales to Ultimate Consumers	10,867,973	10,433,028	9,012,088	8,637,869	7,704,151	8,896,802	11,714,848	14,190,168	14,163,481	9,974,695	7,978,104	8,611,777

	Month & Year (2010)	Jan '10	Feb '10	Mar '10	Apr '10	May '10	Jun '10	Jul '10	Aug '10
kWh Used by Basic Service Customers for Month (b)	Residential-- Non Low Income	8,390,418	7,432,987	6,582,430	5,593,452	6495696	6,615,006	9,795,770	12,332,755
	Residential -- Low Income	163,411	147,137	130,654	112,666	112414	97,857	113,203	116,338
	Residential -- Time-of-Use	0	0	0	0	0	0	0	0
	Small Commercial & Industrial	1,679,456	1,544,046	1,453,946	1,370,910	1429716.5	1,522,348	2,091,293	2,629,880
	Medium Commercial & Industrial	712,825	551,308	530,432	501,858	543386	738,389	1,006,720	1,098,371
	Large Commercial & Industrial	131,800	122,400	132,800	128,200	135400	149,600	163,200	168,000
	Farms	0	0	0	0	0	0	0	0
	Street Lights	9,371	7,458	6,905	6,513	7859.5	5,087	5,283	5,508
	Total Sales to Ultimate Consumers	11,087,281	9,805,336	8,837,167	7,713,599	8724472	9,128,287	13,175,469	16,350,852

Appendix 5: Municipal Electricity Consumption, (Patterson, 2010c)

	Use/Charges	Aug '08	Sep '08	Oct '08	Nov '08	Dec '08	Jan '09	Feb '09	Mar '09	Apr '09	May '09	Jun '09	Jul '09	Aug '09
Nantucket Town	nGrid Charges	$10,737	$9,738	$9,295	$9,454	$10,101	$9,288	$8,773	$8,979	$8,335	$9,269	$9,782	$10,518	$11,087
	Supplier Charges	$11,819	$10,575	$10,353	$10,043	$11,275	$10,082	$9,256	$9,749	$8,856	$8,931	$10,182	$11,398	$11,843
	Total Charges	$22,556	$20,313	$19,649	$19,497	$21,376	$19,369	$18,029	$18,728	$17,191	$18,200	$19,965	$21,916	$22,929
	Total kWh	107845	96496	94478	91640	102888	91287	83766	88226	80145	80820	92149	103148	107174
	Rate / kWh	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.22	$0.21	$0.21	$0.23	$0.22	$0.21	$0.21
Nantucket Schools	nGrid Charges	$10,249	$10,453	$13,627	$12,363	$12,679	$13,063	$11,671	$13,662	$10,417	$13,025	$8,842	$7,852	$8,583
	Supplier Charges	$17,424	$18,634	$24,506	$21,754	$22,587	$23,346	$20,995	$26,547	$18,803	$23,072	$14,701	$13,534	$14,206
	Total Charges	$27,674	$29,086	$38,134	$34,117	$35,266	$36,409	$32,666	$40,209	$29,219	$36,098	$23,543	$21,386	$22,789
	Total kWh	159040	170080	223680	198560	206160	211280	190000	240240	170160	208800	133040	122480	128560
	Rate / kWh	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17	$0.18	$0.17	$0.18
Nantucket Fire	nGrid Charges	$1,675	$605	$637	$700	$669	$789	$660	$787	$775	$642	$677	$817	$792
	Supplier Charges	$2,067	$744	$741	$818	$781	$927	$777	$948	$933	$749	$791	$961	$933
	Total Charges	$3,741	$1,348	$1,378	$1,519	$1,450	$1,716	$1,437	$1,735	$1,709	$1,391	$1,468	$1,778	$1,725
	Total kWh	18864	6787	6763	7470	7124	8455	7033	8580	8447	6774	7160	8700	8441
	Rate / kWh	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20	$0.21	$0.21	$0.20	$0.20
Nantucket DPW	nGrid Charges	$51,004	$22,283	$25,442	$30,516	$31,698	$27,268	$26,647	$28,220	$26,253	$41,107	$56,738	$50,520	$56,744
	Supplier Charges	$25,291	$24,973	$25,258	$28,038	$29,757	$26,984	$28,834	$28,552	$22,057	$26,121	$25,363	$24,163	$29,957
	Total Charges	$76,295	$47,255	$50,699	$58,555	$61,455	$54,252	$55,482	$56,773	$48,310	$67,228	$82,100	$74,683	$86,700
	Total kWh	419424	261234	281534	326715	344477	305998	319443	329793	284213	402888	450027	408570	477200
	Rate / kWh	$0.18	$0.18	$0.18	$0.18	$0.18	$0.18	$0.17	$0.17	$0.17	$0.17	$0.18	$0.18	$0.18
Nantucket Airport	Supplier Charges	$10,654	$8,956	$9,246	$10,148	$12,431	$11,911	$10,967	$12,605	$10,191	$11,327	$15,032	$14,816	$16,107
	Total Charges	$18,264	$15,194	$15,879	$17,346	$21,148	$20,359	$18,702	$20,885	$17,248	$19,910	$25,788	$25,548	$27,692
	Total kWh	97244	81745	84390	92628	112574	107788	99253	114073	92226	102510	136040	134078	145762
	Rate / kWh	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.18	$0.19	$0.19	$0.19	$0.19	$0.19
Nantucket Water	nGrid Charges	$6,871	$4,356	$3,435	$2,446	$2,565	$2,292	$1,988	$2,204	$2,155	$3,639	$5,163	$5,673	$5,972
	Supplier Charges	$10,905	$6,780	$4,480	$3,322	$3,550	$3,028	$2,608	$2,879	$3,085	$4,790	$7,451	$8,350	$8,919
	Total Charges	$17,777	$11,136	$7,916	$5,769	$6,116	$5,320	$4,596	$5,083	$5,240	$8,429	$12,614	$14,023	$14,891
	Total kWh	99537	61883	40894	30322	32137	27404	23603	26058	27917	43352	67433	75565	80715
	Rate / kWh	$0.18	$0.18	$0.19	$0.19	$0.19	$0.19	$0.19	$0.20	$0.19	$0.19	$0.19	$0.19	$0.18
Nantucket NRTA	nGrid Charges	$369	$319	$114	$81	$32	$54	$52	$114	$145	$370	$500	$469	$472
	Supplier Charges	$451	$397	$128	$88	$28	$55	$53	$131	$169	$440	$597	$559	$563
	Total Charges	$820	$716	$242	$169	$59	$109	$105	$245	$314	$810	$1,097	$1,028	$1,034
	Total kWh	4117	3626	1166	800	252	501	480	1187	1533	3980	5406	5061	5094
	Rate / kWh	$0.20	$0.20	$0.21	$0.21	$0.24	$0.22	$0.22	$0.21	$0.20	$0.20	$0.20	$0.20	$0.20

Sep '09	Oct '09	Nov '09	Dec '09	Jan '10	Feb '10	Mar '10	Apr '10	May '10	Jun '10	Jul '10	Aug '10	Sept '10
$9,405	$8,558	$9,193	$9,690	$8,945	$9,259	$9,432	$8,594	$9,259	$11,116	$11,772	$11,104	$9,744
$10,882	$9,670	$10,485	$10,991	$10,204	$9,931	$9,608	$8,676	$8,443	$10,843	$11,956	$11,345	$10,062
$20,287	$18,228	$19,677	$20,680	$19,150	$19,190	$19,040	$17,270	$17,701	$21,959	$23,727	$22,449	$19,805
98477	87511	94884	99464	92346	89871	86947	78519	76404	98130	108195	102669	91056
$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.22	$0.22	$0.23	$0.22	$0.22	$0.22	$0.22
$10,851	$11,531	$12,168	$11,752	$12,407	$12,813	$13,036	$10,659	$12,951	$12,166	$10,833	$11,055	$12,143
$19,704	$21,464	$23,178	$22,383	$22,807	$22,418	$22,356	$17,167	$20,270	$18,644	$17,105	$16,699	$19,802
$30,556	$32,995	$35,346	$34,135	$35,214	$35,231	$35,392	$27,826	$33,222	$30,810	$27,939	$27,753	$31,944
178320	194240	209760	202560	206400	202880	202320	155360	183440	168720	154800	151120	179200
$0.17	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17	$0.18	$0.18	$0.18	$0.18	$0.18	$0.18
$558	$565	$569	$688	$923	$906	$1,074	$859	$890	$783	$764	$698	$618
$663	$671	$677	$822	$1,069	$1,012	$1,200	$960	$961	$847	$827	$757	$686
$1,221	$1,236	$1,246	$1,510	$1,992	$1,918	$2,274	$1,820	$1,851	$1,629	$1,591	$1,455	$1,303
5996	6073	6123	7439	9673	9156	10863	8690	8700	7664	7484	6847	6205
$0.20	$0.20	$0.20	$0.20	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21
$47,917	$47,827	$47,339	$58,182	$51,754	$56,172	$54,724	$44,128	$50,913	$63,035	$61,603	$63,554	$57,779
$26,860	$29,045	$29,529	$38,802	$33,616	$35,844	$29,787	$23,615	$26,752	$29,162	$30,661	$29,876	$24,034
$74,776	$76,872	$76,868	$96,984	$85,369	$92,015	$84,512	$67,743	$77,665	$92,197	$92,264	$93,430	$81,813
416176	438653	440027	551253	471615	503177	460368	367311	421503	498505	497676	504073	447305
$0.18	$0.18	$0.17	$0.18	$0.18	$0.18	$0.18	$0.18	$0.18	$0.18	$0.19	$0.19	$0.18
$13,716	$13,256	$14,771	$20,971	$18,776	$18,537	$16,578	$13,010	$14,081	$16,871	$17,171	$17,234	$19,061
$22,910	$22,122	$24,575	$34,509	$31,015	$31,409	$28,202	$22,439	$25,273	$29,883	$30,411	$30,564	$29,731
124124	119965	133676	189785	169922	167754	150023	117741	127434	152675	155390	155967	172499
$0.18	$0.18	$0.18	$0.18	$0.18	$0.19	$0.19	$0.19	$0.20	$0.20	$0.20	$0.20	$0.17
$4,390	$3,017	$1,962	$2,085	$1,912	$1,928	$2,137	$2,260	$4,483	$6,430	$7,900	$7,470	$5,176
$6,741	$3,871	$2,655	$2,844	$2,567	$2,718	$2,727	$2,934	$5,634	$8,716	$10,709	$10,154	$7,255
$11,131	$6,888	$4,617	$4,929	$4,479	$4,645	$4,865	$5,194	$10,118	$15,147	$18,608	$17,624	$12,432
61006	35028	24028	25738	23233	24595	24683	26551	50988	78880	96911	91889	65659
$0.18	$0.20	$0.19	$0.19	$0.19	$0.19	$0.20	$0.20	$0.20	$0.19	$0.19	$0.19	$0.19
$490	$96	$46	$42	$40	$44	$64	$64	$472	$464	$536	$538	$390
$601	$109	$46	$42	$42	$45	$73	$72	$530	$522	$599	$601	$452
$1,091	$205	$92	$83	$83	$89	$137	$136	$1,002	$985	$1,135	$1,140	$842
5436	983	418	377	383	410	662	653	4798	4720	5418	5442	4093
$0.20	$0.21	$0.22	$0.22	$0.22	$0.22	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21	$0.21

Appendix 6: Various Calculations

	Peak Power Spikes (MW)					
Year	**Business as Usual**	**-1%**	**-5%**	**-7%**	**-10%**	**-12%**
96	23.500	23.265	22.325	21.855	21.150	20.680
97	23.5	23.265	22.325	21.855	21.15	20.68
98	25.44	25.1856	24.168	23.6592	22.896	22.3872
99	27.15	26.8785	25.7925	25.2495	24.435	23.892
00	28.429	28.14471	27.00755	26.43897	25.5861	25.01752
01	31	30.69	29.45	28.83	27.9	27.28
02	32.41	32.0859	30.7895	30.1413	29.169	28.5208
03	33.26	32.9274	31.597	30.9318	29.934	29.2688
04	33.117	32.78583	31.46115	30.79881	29.8053	29.14296
05	36.491	36.12609	34.66645	33.93663	32.8419	32.11208
06	39.1	38.709	37.145	36.363	35.19	34.408
07	38.517	38.13183	36.59115	35.82081	34.6653	33.89496
08	37.781	37.40319	35.89195	35.13633	34.0029	33.24728
09	39.175	38.78325	37.21625	36.43275	35.2575	34.474
10	40.121	39.71979	38.11495	37.31253	36.1089	35.30648

(D. Fredericks personal communication, De2010)

Table 11: Peak Power Spikes (MW)

		kWh					
	¢	Total Norm	5%	7%	10%	12%	20%
SUMMER OFF PEAK	0.087	23,454,042	24,076,026	24,324,820	24,698,011	24,946,805	25941979.7
SUMMER ON PEAK	0.221	12,439,689	11,817,705	11,568,911	11,195,720	10,946,926	9951751.301
TOTAL		35,893,731	35,893,731	35,893,731	35,893,731	35,893,731	35,893,731
WINTER OFF PEAK	0.087	34,983,788	35,843,495.30	36,187,378.41	36,703,203.08	37,047,086.19	38,422,618.64
WINTER ON PEAK	0.108	17,194,156	16,334,448	15,990,565	15,474,740	15,130,857	13,755,324
TOTAL		47,554,962	47,554,962	47,554,962	47,554,962	47,554,962	47554962
TOTAL Year		83,448,693					
		Dollars					
		Total Norm	5%	7%	10%	12%	20%
SUMMER OFF PEAK		$ 2,040,502	$ 2,094,614	$ 2,116,259	$ 2,148,727	$ 2,170,372	$ 2,256,952
SUMMER ON PEAK		$ 2,749,171	$ 2,611,713	$ 2,556,729	$ 2,474,254	$ 2,419,271	$ 2,199,337
TOTAL		$ 4,789,673	$ 4,706,327	$ 4,672,989	$ 4,622,981	$ 4,589,643	$ 4,456,289
WINTER OFF PEAK		$ 3,043,590	$ 3,118,384	$ 3,148,302	$ 3,193,179	$ 3,223,096	$ 3,342,768
WINTER ON PEAK		$ 1,856,969	$ 1,764,120	$ 1,726,981	$ 1,671,272	$ 1,634,133	$ 1,485,575
TOTAL		$ 4,900,558	$ 4,882,504	$ 4,875,283	$ 4,864,451	$ 4,857,229	$ 4,828,343
COST/Year		$ 9,690,231	$ 9,588,831	$ 9,548,272	$ 9,487,432	$ 9,446,872	$ 9,284,632

(New Hampshire Electric Cooperative, Inc, 2009; Department of Energy Resources, 2001-2010)

Table 12: Variable Peak Production

National Grid Residential Rates	2009											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Distribution charge ¢/kWh	3.351	3.351	3.351	3.351	3.351	3.351	3.351	3.351	3.351	3.351	3.351	3.351
Transmission Charge ¢/kWh	1.729	1.729	1.729	1.729	1.729	1.729	1.729	1.729	1.729	1.729	1.729	1.729
Cable Surcharge ¢/kWh	1.834	1.834	1.834	1.834	1.834	2.958	2.958	2.958	2.958	1.834	1.834	1.834
Energy Efficiency Charge ¢/kWh	0.596	0.596	0.596	0.596	0.596	0.596	0.596	0.596	0.596	0.596	0.596	0.596
Renewables Charge ¢/kWh	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Supply Charge ¢/kWh	13.68	13.832	12.239	11.626	9.21	9.505	9.939	10.128	9.714	9.714	8.639	8.639
CHARGE per $/ kWh	$ 0.21	$ 0.21	$ 0.20	$ 0.19	$ 0.17	$ 0.18	$ 0.19	$ 0.19	$ 0.18	$ 0.17	$ 0.16	$ 0.16

National Grid Residential Rates	2010							
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Distribution charge ¢/kWh	3.351	3.351	3.351	3.351	3.351	3.351	3.351	3.351
Transmission Charge ¢/kWh	1.729	1.729	1.729	1.729	1.729	1.729	1.729	1.729
Cable Surcharge ¢/kWh	1.834	1.834	1.834	1.834	1.834	2.958	2.958	2.958
Energy Efficiency Charge ¢/kWh	0.596	0.596	0.596	0.596	0.596	0.596	0.596	0.596
Renewables Charge ¢/kWh	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Supply Charge ¢/kWh	8.828	8.828	8.828	8.828	8.828	8.110	8.110	8.110
CHARGE per $/ kWh	$ 0.16	$ 0.16	$ 0.16	$ 0.16	$ 0.16	$ 0.17	$ 0.17	$ 0.17

(National Grid, 2010a)

Table 13: Residential Rates

Utility Company Name	Smart Meter Cost
BGE	$ 230.62
CenterPoint Energy	$ 266.50
Central Vermont Public Service	$ 266.67
Consolidated Edison	$ 148.50
Idaho Power Corporation	$ 141.80
Modesto Irrigation District	$ 199.07
New York State Electric & Gas	$ 156.08
Oncor	$ 202.94
Pacific Gas & Electric	$ 226.06
PPL Electric Utilities Corporation	$ 123.08
Portland General Electric	$ 155.35
Rochester Gas & Electric	$ 135.22
Sacramento Municipal	$ 135.00
San Diego Gas & Electric	$ 230.43
Southern California Edison	$ 323.58
Texas New Mexico Power	$ 532.47
U.S. Average	$ 217.09

Adapted From (King, 2010)

	Average Cost	Exaggerated Costs
Residential Meters	11471	11471
Meter Cost	$ 221.00	$ 530.00
Total Cost	$ 2,535,091	$ 6,079,630

Table 14: Smart Grid Costs

Appendix 7: Monthly Wind Calculations

Height	58	68	99	avg 58/68/9	37
September	6.7	7	7.7	7.13	-
October	9	9.4	10.2	9.53	-
November	9.1	9.7	10.8	9.87	-
December	9	9.4	10.1	9.50	-
January	9.5	10.1	11.1	10.23	-
February	9.6	10.1	10.9	10.20	-
March	8.1	8.6	9.3	8.67	-
April	8.6	9	10	9.20	-
May	8.3	8.7	9.9	8.97	-
June	8.1	8.7	9.9	8.90	-
July	7.4	8	9.2	8.20	-
August	6.4	6.7	7.5	6.87	-
Average	8.32	8.78	9.72	8.94	7.17

igh School 100kW turbir	
Projected kWh	
Jan	18317
Feb	18257
Mar	15513
Apr	16467
May	16050
Jun	15930
Jul	14677
Aug	12291
Sep	12768
Oct	17064
Nov	17661
Dec	17004
Annual*	192000

*as estimated (Alteris Energy, 2010)

Madaket 1.5MW turbine	
Projected kWh	
January	451246
February	449776
March	382163
April	405681
May	395392
June	392452
July	361585
August	302791
September	314549
October	420379
November	435078
December	418909
Annual**	4730000

** as estimated (R. Patterson, data set)

Combined Wind Turbines		
	kWh	MWh
Jan	469563	469.6
Feb	468034	468.0
Mar	397676	397.7
Apr	422148	422.1
May	411441	411.4
Jun	408382	408.4
Jul	376262	376.3
Aug	315081	315.1
Sep	327318	327.3
Oct	437443	437.4
Nov	452738	452.7
Dec	435914	435.9
Annually	4922000	4922.0

Photovoltaic Energy		
Solar	2MWh Farm	4*2MWh Farms
Jan	163.77	655.1
Feb	173.55	694.2
Mar	221.21	884.8
Apr	236.72	946.9
May	256.55	1026.2
Jun	252.08	1008.3
Jul	259.35	1037.4
Aug	251.23	1004.9
Sep	224.71	898.8
Oct	204.41	817.7
Nov	167.21	668.8
Dec	155.48	621.9
Annually	2566.3	10265.1

Savings on Electricity- Renewable				
	Rate/ kwh	Cost wind	Cost solar	Cost combo
Jan	0.1368	64236	89617	153854
Feb	0.13832	64738	96022	160760
Mar	0.12239	48672	108294	156966
Apr	0.11626	49079	110084	159163
May	0.0921	37894	94512	132406
Jun	0.09505	38817	95841	134658
Jul	0.09939	37397	103107	140503
Aug	0.10128	31911	101780	133692
Sep	0.09714	31796	87312	119108
Oct	0.09714	42493	79427	121920
Nov	0.08639	39112	57781	96893
Dec	0.08639	37659	53728	91387
	$savings/yr	523803	1077507	1601310

	with Wind	with Solar	Combined	2009 Electric	Wind (MW)	Solar (MW)	Combined
Jan	10398	10213	9743	10868	470	655	1125
Feb	9965	9739	9271	10433	468	694	1162
Mar	8614	8127	7730	9012	398	885	1283
Apr	8216	7691	7269	8638	422	947	1369
May	7293	6678	6267	7704	411	1026	1438
Jun	8488	7888	7480	8897	408	1008	1417
Jul	11339	10677	10301	11715	376	1037	1414
Aug	13875	13185	12870	14190	315	1005	1320
Sep	13836	13265	12937	14163	327	899	1226
Oct	9537	9157	8720	9975	437	818	1255
Nov	7525	7309	6857	7978	453	669	1122
Dec	8176	7990	7554	8612	436	622	1058
Annually	117263	111920	106998	122185	4922	10265	15187

Appendix 8: Projections of People

Tons/Mo.*												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2006							1885.1	2018.48	1320.72	976.05	775.25	700.03
2007	591.21	492.84	571.46	713.14	1016.49	1212.47	1805.76	1898.45	1217.7	928.06	706.56	676.01
2008	581.11	506.38	533.92	597.13	828.07	1093.22	1726.78	1740.46	1045.78	737.07	531.9	547.96
2009	437.06	355.61	386.52	480.89	581.48	951.78	1690.86	1830.11	1137.58	755.35	570.99	643.2
2010	500.75	427.64	437.89	601.39	733.1	1167.39	1583.29	1824.35	1090.29	845.1		

*(Nantucket Department of Public Works, 2010)

People/Mo.**												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2006							50747	54337	35554	26275	20870	18845
2007	15915	13267	15384	19198	27364	32639	48611	51106	32780	24983	19020	18198
2008	15643	13632	14373	16075	22292	29429	46485	46853	28152	19842	14319	14751
2009	11766	9573	10405	12945	15653	25622	45518	49266	30623	20334	15371	17315
2010	13480	11512	11788	16189	19735	31426	42622	49111	29350	22750		
Ave.	14201	11996	12987	16102	21261	29779	46796	50135	31292	22837	17395	17277

** Calculated based on February 2010 at current census number and tons of trash per month (M. Altreuter, personal communication, October 25, 2010)

kWh- Res												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2006							8251900	11087842	9948444	6640251	5922081	6941957
2007	7783493	7751887	8103725	6724716	6032393	6425581	7998944	10969204	10585963	6868949	5970249	7967273
2008	8669686	7555419	6874356	6607851	5536287	6528167	9073467	11924791	10313512	6748775	6190011	7356121
2009	8130017	7743458	6645552	6196766	5391832	6172715	8425869	10574288	10331559	6972495	5677593	6408962
2010	8390418	7432987	6582430	5593452	6495696	6615006	9795770	12332755				

kWh/Person***												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2006							232	306	394	381	388	509
2007	646	757	669	459	302	273	222	285	433	378	429	571
2008	705	714	615	548	338	303	259	336	492	482	617	665
2009	924	1090	866	667	492	347	257	288	463	491	519	497
2010	727	768	654	539	463	419	384					

Aggregate Nantucket Electrical Energy (kWh)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001								11627877	13126351	9554148	8200079	94425
2002	9936555	9269309	8548269	8724229	7040892	8931414	10919073	12828933	13024960	10012773	9219589	108357
2003	12152189	11859663	10933451	9605972	8613690	9716839	11158050	14076690	13506389	10133576	8836813	110593
2004	12061079	12330339	10167675	9462334	9022350	9502780	12046043	12637955	14418036	10547076	9304677	109291
2005	11325391	10585256	11486584	9322271	8629344	10177404	11801300	15122537	15152709	11152330	8953859	109645
2006	11628409	8939011	10266894	8578999	8106300	9385693	11798152	16633820	14006877	10002516	8088812	95826
2007	10285803	10044796	10291986	8810309	8261468	8905107	10813406	14586299	14208958	9453818	8152202	103983
2008	11021053	9727667	8833420	8807237	7528355	8910372	12044929	15751649	13861765	9568645	8841696	98043
2009	10867973	10433028	9012088	8637869	7704151	8896802	11714848	14190168	14163481	9974695	7978104	86117
2010	9805336	8837167	7713599	8724472	9128287	13175469	16350852					

Aggregate Nantucket Electrical Energy (MWh)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001								11628	13126	9554	8200	94
2002	9937	9269	8548	8724	7041	8931	10919	12829	13025	10013	9220	108
2003	12152	11860	10933	9606	8614	9717	11158	14077	13506	10134	8837	110
2004	12061	12330	10168	9462	9022	9503	12046	12638	14418	10547	9305	109
2005	11325	10585	11487	9322	8629	10177	11801	15123	15153	11152	8954	109
2006	11628	8939	10267	8579	8106	9386	11798	16634	14007	10003	8089	95
2007	10286	10045	10292	8810	8261	8905	10813	14586	14209	9454	8152	103
2008	11021	9728	8833	8807	7528	8910	12045	15752	13862	9569	8842	98
2009	10868	10433	9012	8638	7704	8897	11715	14190	14163	9975	7978	86
2010	9805	8837	7714	8724	9128	13175	16351					

Appendix 9: Preamble for Interviews

We are students from Worcester Polytechnic Institute working with the Nantucket Energy Study Committee on a project that will be researching the potential for Nantucket Island in Massachusetts to install a Smart Grid system. We would like to conduct an interview with you that would last no longer than 60 minutes. All information and quotations from this interview will only be used to aid us in our project, and will be kept confidential unless you give us permission to use your name for anything you may say during this interview. If we plan to use any information or quotations from this interview we will send you a copy of our report via email for you to look over. During the interview, you may skip any questions you do not wish to answer, end the interview at any time, and change your mind about any information you provide us as well as how we may use this information. Will you allow us to interview you? *(If yes, then reply with a thank you, and if a recording device is readily available ask the interviewee if he would mind if the interview is recorded.)*

Appendix 10: Preamble to Survey

Hello. My name is ___________ and I am here with my project group from Worcester Polytechnic Institute. We are currently working on a project for the Nantucket Energy Study Committee and are taking a survey on the energy use of Nantucket residents and energy conservation tactics. Would you mind taking a survey for use in our study? I assure you that all information is confidential and would be solely used for our study. If you prefer not to answer any question, you may back out at any time. Also, for the purposes of our study, we ask if you will provide your most energy bill. All confidential information will be blocked out and only the energy related information will remain.

Appendix 11: Residential Survey

Methodology:

Our several attempts at pilot surveys of residential customers convinced us that a scientific survey would not be feasible or of much value for our profile, due to the lack of participation from residents. The purpose of the surveys was gain the trust of the residents to acquire their past year's energy data. The energy data can be found in KWH on the side of their bill. We found that very few residents were willing to share their bill with us. The aggregate data from the Migration Reports proved more useful in our final analysis.

The medium and small commercial energy consumers comprised a large pool of possible interviewees. These businesses were identified as retail stores, inns and hotels, and other large business operations on the island, such as construction companies, a yacht club, and a marina. We incorporated the gamut of businesses in order to create an accurate energy profile for each sector. The brief commercial preamble included a detailed description stating who we were, what our project was about, and assured them that all data collected from them would be kept confidential if they wished. At the end of the interview we asked if they could provide their most recent energy bill, so that we could record the number of kWh used on a monthly basis and identify their National Grid classification (G1 or G2?). The data were cataloged into a Microsoft Excel chart following each interview. The information that we found most useful from these interviews were energy conservation plans being implemented. We used the aggregate data from the migration reports and pertinent energy information gleaned from interviews with the commercial establishments to create profiles.

Preamble:

Hello. My name is _______ and I am a student from Worcester Polytechnic Institute working on a study that is part of our degree requirement. We are currently researching energy consumption on the island. We are working with some Nantucket town officials. To further our research, we are taking a survey of residential energy consumption. Would you mind participating in our survey for research purposes only? I assure you that all information is confidential and would be solely used for our study. If you feel uncomfortable of do not want to share certain information with us you don’t have to answer all the questions. Would you like to continue?

If yes, proceed with survey.

Also, for the purposes of our study, we ask if you wouldn't mind us taking a picture of your most recent electric bill. We assure you that all confidential information will be blocked out and only the energy related information will remain, and will be used only for our study.

<u>Survey:</u>

Date: Times: Surveyors:

Survey #	Street Address	National Grid Rate Sector	Full Time Residency			Square Footage (ft^2)	# of Adult	# of Children	Energy Star Efficient Appliances
			Months of the Year in House		If yes, do you work out of the house?				
			___Yes ___ No	(Months)	___Yes ___ No				___A/C ___Computer ___Dishwasher ___Light bulbs ___Stove ___Fridge ___TV ___Water heater ___Washer/Dryer ___Windows ___(Other) ______________________________
			___Yes ___ No	(Months)	___Yes ___ No				___A/C ___Computer ___Dishwasher ___Light bulbs ___Stove ___Fridge ___TV ___Water heater ___Washer/Dryer ___Windows ___(Other) ______________________________
			___Yes ___ No	(Months)	___Yes ___ No				___A/C ___Computer ___Dishwasher ___Light bulbs ___Stove ___Fridge ___TV ___Water heater ___Washer/Dryer ___Windows ___(Other) ______________________________

Central A/C?			Window Units? (# Units)			Electric Heat?			Automatic Thermostat?	Insulation?	Electric Water Heater?	Electric Well Water Pump?	Electric Stove/ Oven?	Do you use more than one fridge?	
Summer/Winter Temp. Setting (°F)		How often is it used?	How often is this used?			Temp. Setting (°F)		Amount used?						If so, how many?	
___Yes ___No	__°F Summer ___ °F Winter	___Always ___At Night ___When it is hot	___Yes ___No	#	___Always ___At Night ___When it is hot	___Yes ___No	°F	__Always __Sometimes __Never	___Yes ___No	___Yes ___No	___Yes ___No	___Yes ___No	___Yes ___No	___Yes ___No	#
___Yes ___No	__°F Summer ___ °F Winter	___Always ___At Night ___When it is hot	___Yes ___No	#	___Always ___At Night ___When it is hot	___Yes ___No	°F	__Always __Sometimes __Never	___Yes ___No	___Yes ___No	___Yes ___No	___Yes ___No	___Yes ___No	___Yes ___No	#
___Yes ___No	__°F Summer ___ °F Winter	___Always ___At Night ___When it is hot	___Yes ___No	#	___Always ___At Night ___When it is hot	___Yes ___No	°F	__Always __Sometimes __Never	___Yes ___No	___Yes ___No	___Yes ___No	___Yes ___No	___Yes ___No	___Yes ___No	#

# of Computers in Use?		# of TV's in Use		Gas Dryers?	Heated Pool?	Energy Efficient Light Bulbs?	Turn off lights when leaving a room?	Electric Cars?	Relaxed or Attentive?	Willingness to Change Energy Habits?		Additional Comments
How much do you use them?		How much do you use them?										
___Yes ___No	___Always ___Sometimes ___Never	___Yes ___No	___Always ___Sometimes ___Never	___Yes ___No	___Yes ___No	___Yes ___No	___Yes ___No	___Yes ___No	___ Relaxed ___ Attentive	____Very ____Willing	____Not So ____Not	
___Yes ___No	___Always ___Sometimes ___Never	___Yes ___No	___Always ___Sometimes ___Never	___Yes ___No	___Yes ___No	___Yes ___No	___Yes ___No	___Yes ___No	___ Relaxed ___ Attentive	____Very ____Willing	____Not So ____Not	
___Yes ___No	___Always ___Sometimes ___Never	___Yes ___No	___Always ___Sometimes ___Never	___Yes ___No	___Yes ___No	___Yes ___No	___Yes ___No	___Yes ___No	___ Relaxed ___ Attentive	____Very ____Willing	____Not So ____Not	

Table 15: Residential Survey

Appendix 12: Industrial and Commercial Energy Use Preamble

We are students from Worcester Polytechnic Institute working with the Nantucket Energy Study Committee on a project that will be researching the potential for Nantucket Island in Massachusetts to install a Smart Grid system. We would like to conduct an interview with you that would last no longer than 60 minutes. All information and quotations from this interview will only be used to aid us in our project, and will be kept confidential unless you give us permission to use your name for anything that you may say during this interview. If we plan to use any information or quotations from this interview we will send you a copy of our report via email for you to look over. During the interview, you may skip any questions you do not wish to answer, change your mind about any information you provide us as well as how we may use this information, and end the interview at any time. Will you allow us to interview you? *(If yes, then reply with a thank you, and if a recording device is readily available ask the interviewee if he would mind if the interview is recorded.)*

Appendix 13: GIS Maps of Proposed Solar Farms

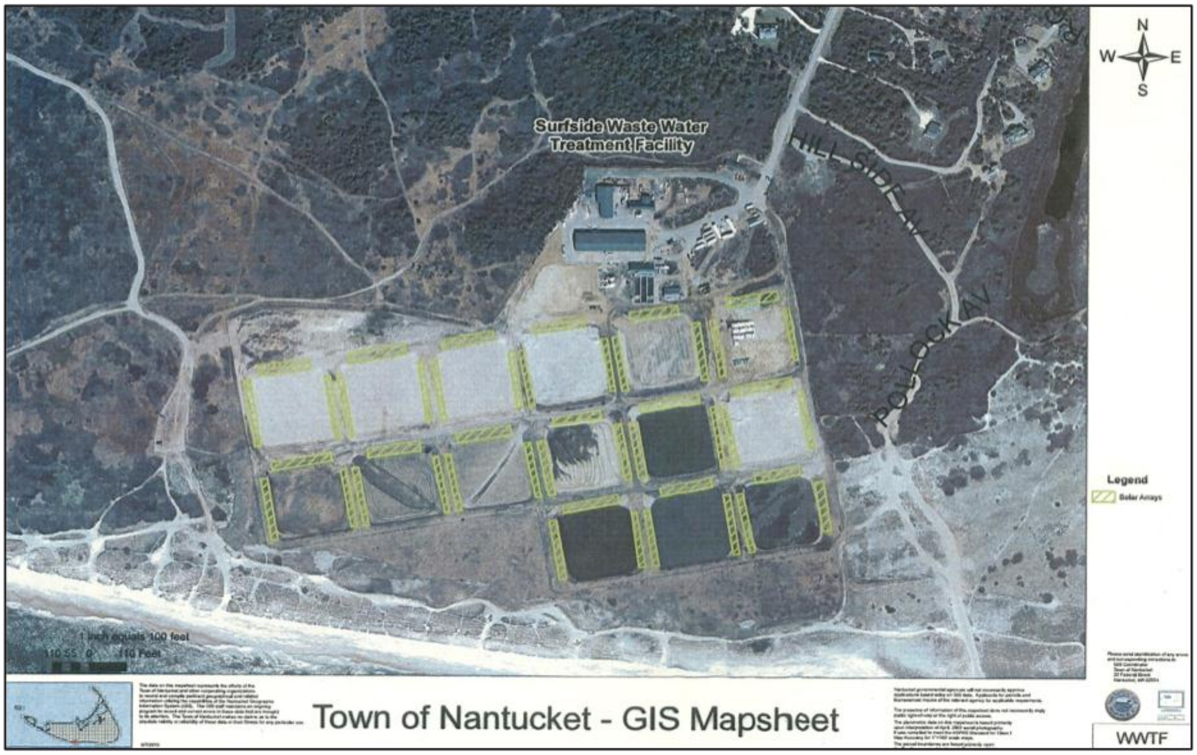

Figure 37: Proposed 2.0 Megawatt Photovoltaic Solar Farm at the Waste Water Treatment Plant

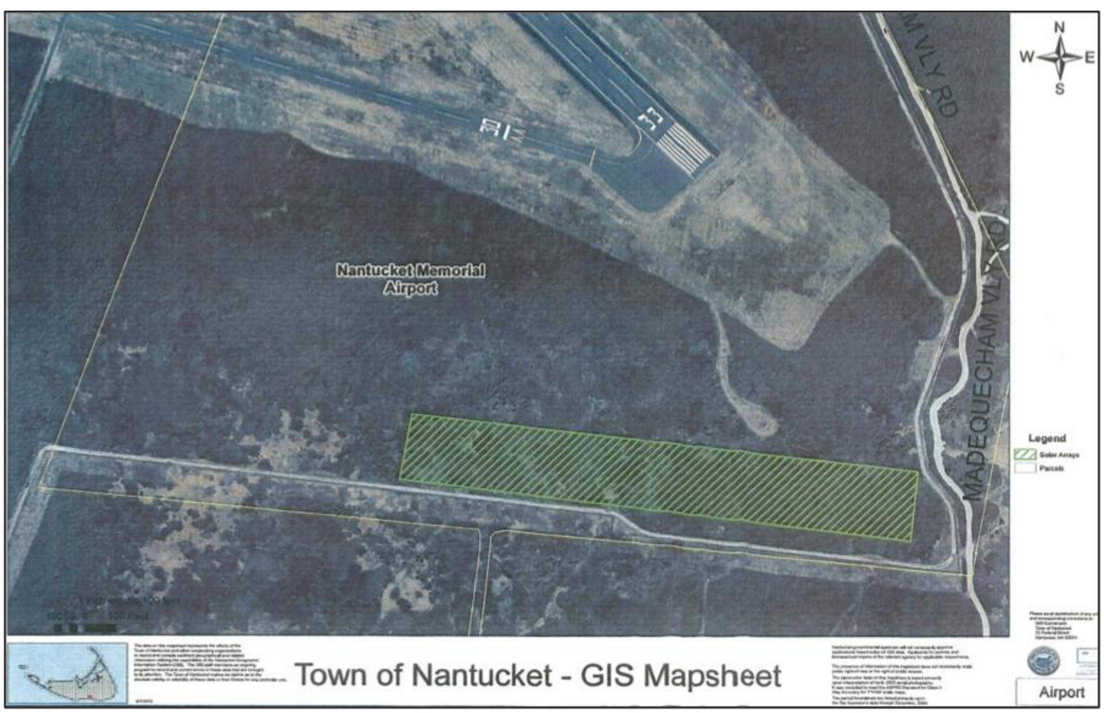

Figure 38: Proposed 2.0 Megawatt Solar Farm at the Nantucket Memorial Airport

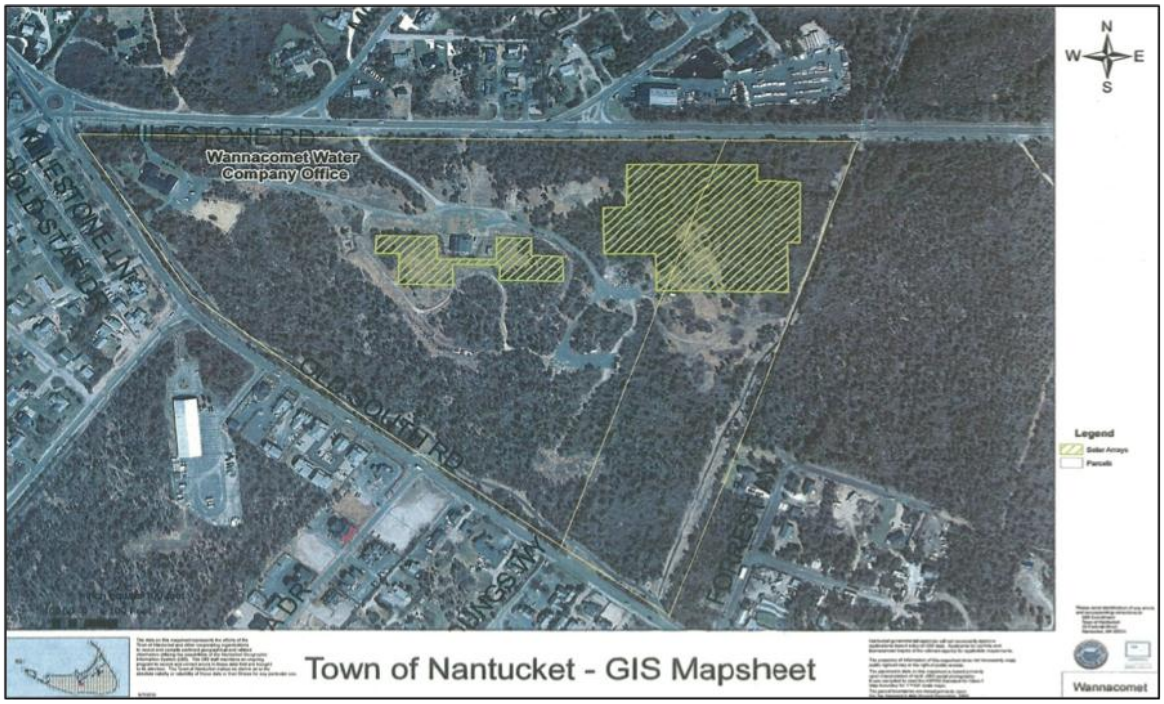

Figure 39: Proposed 2.0 Megawatt Photovoltaic Solar Farm at Weirs Valley (Wannacomet Water Company)

Figure 40: Proposed 1.5 Megawatt Photovoltaic Solar Farm at the Polpis Road Water Tower (Wannacomet Water Company)

Appendix 14: Timeline and Objectives

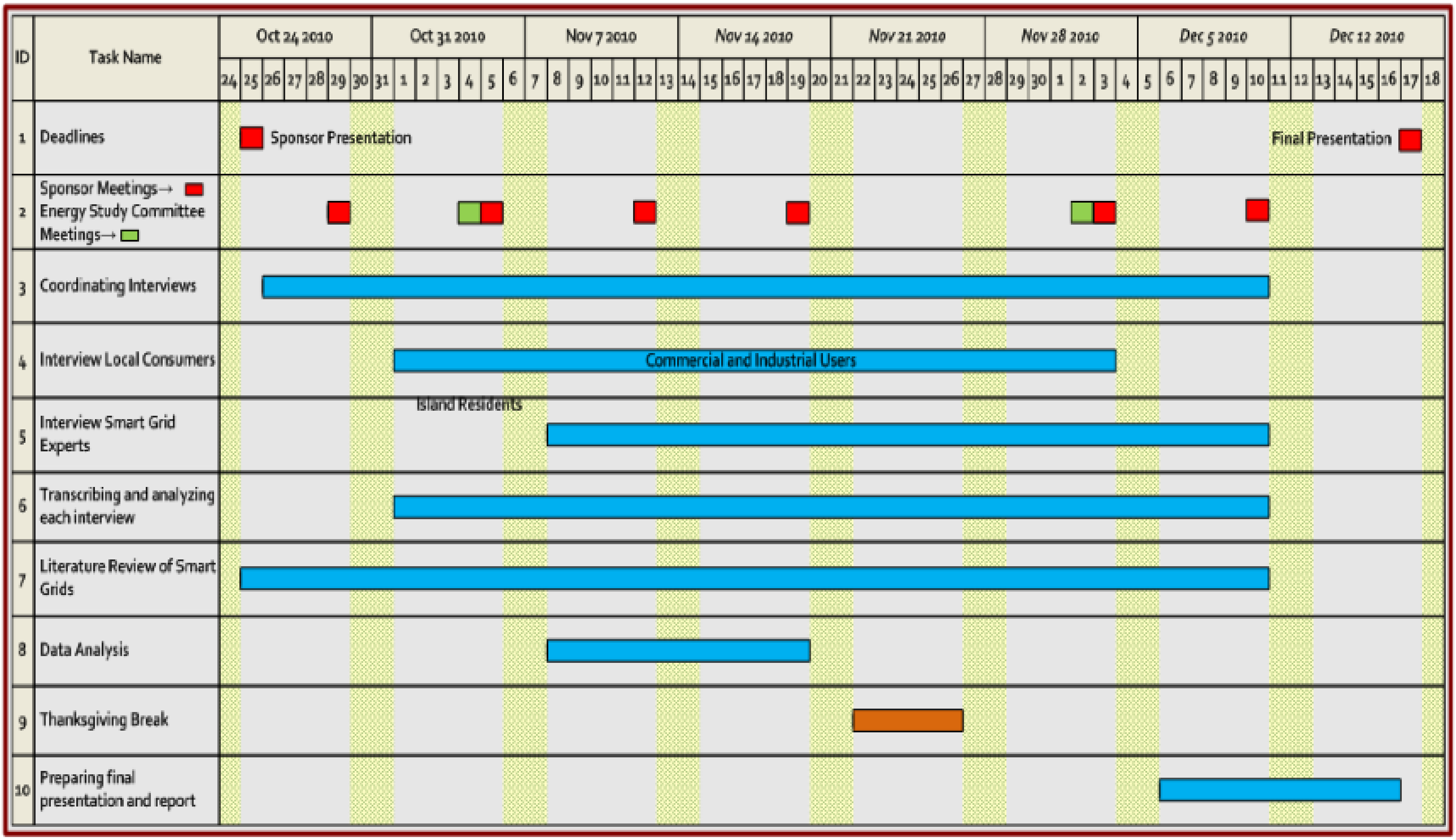

Table 16: Timeline

Appendix 15: John Edwards Phone Interview

John Edwards Phone Interview
September 17, 2010
Begin: 9:25am End: 9:43am
Interviewer K. Colyer Sigety

Background on the project and company:
6 months ago Optimized Energy Networks, LLC contacted Nantucket Island with a proposition to set up a Micro grid/Smart Grid to manage Nantucket Electric Grid. The hook for OEN was when they heard about the Tuckernuck Island Wind project. OEN is a start-up company still in the midst of establishing themselves as a project management team. They are not the installers of a Smart Grid, but they can be the "middleman" for integrating all the companies that would install the Smart Grid. They would research the best installation companies, collaborate on budgetary issues and act as the agent of change for Nantucket Island.

The Idea:
Create a flexible network of storage and electric cars on the island that could utilize energy produced "when the sun is shining, or the wind is up", an energy management system.

The Problem on Nantucket Island as OEN sees it:

- Summer population drives the peak usage of electric on the island.
- When the tourists/summer vacationers leave in august the peak ends.
- Currently Nantucket has 2 30 megawatts cables supplying all energy needs.
- These cables capacity serves the august peak.
- 1 transmission cable is paid for solely by the Nantucket residents.
- They have a deal with National Grid which makes their electric bill higher during peak season and lower in winter but because National Grid chose to install the 2nd cable to ensure that they were able to meet to peak demand (I am assuming this meant that before the 2nd cable there were power outages due to too much draw) and now the Nantucket residents have to pay for National Grid's choice. (His wording not mine/ who knows what the actual deal was between the island and the electric company)
- Because of the extra cable the islands electric bill is 20% higher than average.

OEN plans to take advantage of off peak energy usage problem and help the Nantucket reduce their energy needs during the on-peak and off-peak.
Means of doing this:
Smart Grid
OEN wants to make the town of Nantucket their customers.

Stage 1 of project:

1. Management system for the town building

2. Help the school manage the wind energy they have from their turbine in a more viable fashion.
3. Attack the Industrial buildings by one by one with their own management systems.

Companies that OEN could use to install these systems:

- Itron
- **EnerNoc**
- Emeter

Alternative Energy Initiatives on Nantucket:

- too far down the line (aka in the future)
- how you make it feasible
    - For Tuckernuck island wind energy
        - Would have to route transmission lines all the way from the island to the substation in town, very costly.
        - Think of how long Cape Wind took to go through all the hoops in policy
- End result: OEN is not concentrating on this part; they are just trying to install a Smart Grid that could handle Alternative Energy if Nantucket ever were to receive enough funding to make it happen.

There are two separate parts of a Smart Grid:

1. Data and Communication
2. Actual Transmission lines and electric

Data and Communication:

Network operation center operators could be in the middle of Ohio. (Just a random place thrown out there with very low electric bills, so having a hub of computers computing when and where to send energy is not that expensive to power. The point: Data can be transmitted anywhere in the world to be calculated and sent back to Nantucket Island in milliseconds with the way internet/communication works today)

- Could be transmitted via Ymax
- WiFi: public internet
- Fiber Optics

Data and communication-OEN has not made a decision yet on what company to use for software and data computation.

The Current status of the project:

OEN is working on an agreement with the town of Nantucket and the Administration. This agreement will cover where the funds for this project will originate from.

Budgetary options OEN and Nantucket are playing with:

- Grant from Mass energy center
-

Appendix 16: Interview with Doug Hurley on Smart Grids

Smart Grid Expert Interview: Doug Hurley

Synapse Energy Economics Inc.

December 3rd, 2010

Note: *Below is a transcription of a telephone interview with Mr. Doug Hurley of Synapse Energy Economics Inc., a Cambridge-based consumer advocacy firm that focuses on public utilities. The interview took place in the morning of December 3, 2010 and was recorded using an audio recorder so that it may be transcribed at a later date.*

Colyer: Introduce Doug into our backgrounds, our sponsors, what our project is about and the goals of our project.

Doug Hurley: What we are trying to measure smart grid results in terms of? KWh? Tons of emissions? Costs? Etc.

Colyer: We are trying to get information regarding kW from National Grid. We have obtained data on kWh data. We don't care about carbon footprints. We want the cost reduction from smart grids

Colyer: Would you mind describing to us what your role is within Synapse?

Doug Hurley: Synapse is a small consulting firm that works for consumer advocates and environmental advocates, with all energy policies, mostly electricity and some natural gas information. The company works for people who are consumers and ratepayers, and fighting to make sure that utilities are fair. He has been working on participation in New England and Mid-Atlantic states; he works on influencing the market rules of the purchase agreements in these states. Doug is always working on behalf of consumers. He evaluates proposals from utilities and evaluates the potential changes that would come from the proposals in terms of higher rates and higher emissions.

Doug Hurley: He was hired at Synapse because his previous career was in high-tech applications in Silicon Valley, working with early Internet networks and stuff.

Colyer: Does that make you an advocate of smart grids?

Doug Hurley: I am absolutely an advocate for anything that helps consumers. So far the proposals that Synapse has seen from across the country, Synapse has been opposed.

Colyer: What stakeholders are playing a role?

Doug Hurley: I have not seen any smart grid proposals put forth by anyone other than a utility. When we are talking about a smart grid, we are talking about smart meters that can record sub hourly data and transmit the data to the utility and then back to the consumer.
Colyer: Yes, this is what we believe a smart grid is, but we also consider the components that are on the wires that communicate strictly with the utility about what is happening currently on the wires.

Doug Hurley: Smart grid also means devices that sit on a transmission devices – I'm glad we are on the same page about what a smart grid is.

Doug Hurley: I am also glad that the smart meters we are both talking about have the capabilities to relay current use information, as well as other properties such as: power outages, voltage levels, turn on/off power to your home.

Doug Hurley: The reason the only proposals for smart grids I have seen is because the person that own the meters on your homes and buildings is the utility company. The only person that can touch and replace that meter is the utility company. There is no one else under current rules in all 50 states that can tough a meter in any way. So every smart grid proposals come from utility companies.

Doug Hurley: Utilities say, "smart grid is great, we can do all these things to help improve our efficiency and lower our costs on operations." Utilities can remotely read the meter as opposed to sending a meter-reader around to homes. Utilities have all of these opportunities to save money through automation and technical advances.

Colyer: So where does the customer come into play? It seems like the utility gets so many benefits, does the customer benefit?

Doug Hurley: Exactly. Exactly. All of the things I said before save the utility money, and that should then translate down into lower rates for customers since utilities are seeing lower costs. But there is an interesting thing that deals with the timing of it all.

Doug Hurley: Let's take NSTAR for example. The way that NSTAR figures out the rates that its customers will pay in a certain area will go before the Massachusetts Dept. of Public Utilities (DPU). They will show the DPU all of their costs to provide electricity, and it is a big public hearing that lasts about a year. It takes thousands of pages of documents regarding all of the possible costs that it takes to run their company. The board then determines what an acceptable rate is to charge customers based on how much cost it takes to provide power to its customer. They lay out the cost for supply and deliver for each area. They then leave that rate alone for years. So now, if the utility sees a large reduction in their costs, they don't have to go back to the DPU right away to reevaluate their costs. They can continue to charge the same rates, and then if they lowered their costs, then they are making that much more money off of each customer. To the utility though, this isn't a problem because they want to make as much money as possible. In fact, as a public company, they are legally obligated to make as much money as possible for their shareholders.

Colyer: Yeah, so, may I just interject a question here?

Doug Hurley: Of course.

Colyer: My understanding, now we have looked into National Grid quite a bit, and from what I understand, there is a supply charge, and that comes from whoever is making the power. Then there is a delivery charge, and that comes from whoever is bringing the power to the customer. Now, sometimes these entities are the same, and other times they are not the same company. Now you are saying that these entities, if they are the same or not, have decided the rates that they will charge customers years in advance of when they are actually producing and selling power. Yes?

Doug Hurley: That's true for distribution, not so much for supply.

Colyer: Okay, that's good because I was about to interject my caveat because I have been looking at the various charges, and National Grid has different charges based on season, and it appears that use is being charged differently based on the demand on Nantucket during a given season. Does that make sense?

Doug Hurley: The supply charges, they are related to the demand, but its more that under current regulations, all utilities must put out an RFP (request for proposal) to power producers for residential power supply every 6 months, and every 3 months for commercial and industrial customers. That may be flipped though.

Colyer: I think you're right. I'm looking at the supply charges right now and it appears that they switch exactly when you are suggesting.

Doug Hurley: So yes, it's the distribution charge is the one that gets set at a "rate case" is what they call it. This might only happen every 10 years, and basically it stays in effect either until National Grid decides they want to change the rates, or if the DPU says that they want to change National Grid's rates for them. That's a big long process that requires a lot of time, and money, and lawyers. Both parties have an incentive then to not go through a rate case, since it is so hard, long, and expensive. So to the extent that the utility says they will save a bunch of money with a smart grid and then pass it along to the customers – this is where Synapse raises its hand and says, "woah, woah, woah. That's not necessarily true unless they volunteer to go through the rate case again, and reduce charges to the customer. Don't claim that just because you reduce your costs, the customers will save money – because that's not entirely true." It can mean customers save money, but it doesn't necessarily.

Colyer: Right.

Doug Hurley: That's one reason why Synapse has opposed the smart grid proposals we have seen so far. The big reason Synapse has opposed smart grid proposals though, is because almost every proposal has included pieces called “real-time retail rates” or “real-time rates”. It is suggesting that people would shift their time of use to times in which lower rates in order to save money, and this set of assumptions has a serious group of flaws. The utilities have the idea that if they change your rates, you will automatically adapt to the new rates and save money – and this is not necessarily true. Synapse’s position is that that is not true, and that there are a small number of people who are “electricity geeks” that would make the changes necessary to save money, but that only a small number of people would actually follow through and make the changes. The problem inherently with the pilots that have been done thought is that most people participating are early adopters of new technology, and they will sign up and save, but these numbers may only be 100 out of 10,000 customers. We just haven’t seen that the real-time rates save people money over time; it’s not in the numbers we have seen.

Colyer: Thank you. Do you think that beyond time of use rates that there are other viable things that smart grid could provide the customer, not just the utility?

Doug Hurley: Beyond time of use rates, there are other cool things that a smart grid could do for customers. They could record hourly usage, and then customers could get a notification anytime their usage goes outside of a range of normal kWh consumption. This could tip off customers to strange anomalies that are happening at your house or building, and could serve as a safety feature too. These are secondary things though, and the primary reasoning would be the potential cost savings of a smart grid.

Doug Hurley: The utilities are currently trying to force smart meters and smart grids onto customers, and in my experience from Silicon Valley, that’s not the way that a technology achieves the greatest success. Smart Grid should be rolled out the same way a new cool tech gadget is – where one of your friends gets it, and raves about it, then five of your friends have it and rave about it, and then it grows from there and takes off. If you do this, maybe in ten years time, you will get to this idea of a perfect-world smart grid. You don’t get to the grid-wide savings until the early adopters grow into a significant portion of the consumers on a grid system.

Colyer: Can you install a smart grid on just a few homes; say maybe 1% of a population? Or do you not see any real cost savings until, say, 15% of the population has adopted it?

Doug Hurley: Excellent question. In terms of personal savings, yes, each user can save money to a limited degree based on their restructured rates and lower use. The whole population wont see the savings from remote billing or remote turn off/on your power until enough people are involved that the utility can save costs by laying off meter-readers or linesmen. You can’t let go of employees until you get a certain number of people involved in the smart grid to make it feasible.

Colyer: So other than the smart meters on buildings and the potential for installing devices in the transformers in neighborhoods, and in the current proposals that you have seen, what else comprises smart grids?

Doug Hurley: Each proposal is totally different in terms of pricing and demographics, leading to vastly different scenarios. In terms of hardware, all of the proposals I have seen include smart meters on homes, some sort of in-home monitoring device, a smart thermostat, and some similar devices that allow control over other big devices in the home.

Colyer: What are the price tags that you have seen on all of this?

Doug Hurley: I will send you information from Rick Hornby from Synapse; I will try to send the cost the utility claims it will cost them, not the retail cost to the consumer. Meters range from $600-$1000 each.

Andrew: Viewing slides on Synapse website about cost-effectiveness. Presentation by Rick Hornby.

Andrew: I was wondering if you could give us some information about why some smart grid proposals are very cost-effective, and why some proposals are very not cost-effective?

Doug Hurley: It entirely depends on what the utilities propose. That is what creates the difference in effectiveness. Rural vs. urban populations have a big impact on distribution costs, so an urban smart grid could save more than a rural smart grid. It really comes down to how much do people actively make changes to electric use, what time of day changes are made, and what the rate structure is of each smart grid proposal.
Colyer: Nantucket is interested in pursuing many renewable resources on the island. Do you know what added benefits a smart grid can bring to renewable energy generation?

Doug Hurley: One of my first smart grid projects I did was in San Diego, and there was a tie between smart grids, peak use, and solar panels on resident's homes. The ability to recover the costs of installing renewables such as solar power is greatly increased if you have a smart grid with net metering and time of use/production rates.

Colyer: Combining renewables with smart grid is a wonderful option, yes?

Doug Hurley: Absolutely. Without a doubt.

Mary: Do you see the Bakersfield effect repeating itself in other smart grid installations?

Doug Hurley: Potentially, we saw something similar last year in a Puget Sound pilot study, in which the peak rates were too high and consumers ended up paying much more for electricity than previously was being paid. The concern is that if people don't respond the way you predict, or if the rates are even slightly off, the implications of the overall success of the smart grid is huge.

Mary: Are there regulations in Massachusetts about smart grids yet? What about the new NIST smart grid standards?

Doug Hurley: Nope, not yet in Massachusetts. NIST standards regard mostly to the hardware and software production standards to keep interoperability available.

Andrew: Does it make sense that a utility in Massachusetts would charge a surcharge to its smart grid customers to recoup the cost of installation? Would this make smart grids not feasible on Mantucket?

Doug Hurley: Yes, it is reasonable to assume that any utility would add a surcharge or a tracker to rates on Nantucket. They need to recover the cost of installation and this would make it very easy for the utility to do so. This is why going through a slow rollout of the technology may avoid this problem.

Mary: As a final question, would you mind if we used or quoted any of your information given today in our report or presentations?

Doug Hurley: I wouldn't mind at all. Feel free to use whatever necessary. Thank you for asking, though.