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Evaluating LED Street Lighting

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Submitted: December 18, 2014

WPI

NANTUCKET ENERGY OFFICE

Promoting a sound energy future on Nantucket

Evaluating LED Street Lighting

Nantucket Project Center

An Interactive Qualifying Project Report
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Abstract

The Town of Nantucket has nearly 200 decorative streetlamps that require constant maintenance and repair. The goal of our project was to create a database of the streetlamps and evaluate the feasibility of retrofitting the lights with LEDs. We inventoried the decorative streetlamps, created a database and an interactive map of the streetlamp locations, assessed public opinion about the LED retrofit, and analyzed the economic costs and benefits of the conversion. Based on our findings, we recommend a plan for proactive maintenance and we conclude that an LED conversion would be a feasible option for the Town of Nantucket that would reduce maintenance problems and maintain the desired lighting aesthetics.

Acknowledgments

We would like to thank our advisors, Professor Dominic Golding and Professor Stanley Selkow for their guidance and assistance throughout our project. We appreciate your constructive feedback and providing us with opportunities to experience the community of Nantucket.

We would also like to thank our sponsor, Lauren Sinatra, for the wonderful opportunity to work on this project and taking the time and patience to help us accomplish our objectives. Thank you to the Town of Nantucket Energy Office for sponsoring the project that allowed us to assist the Town in their goal to promote energy efficiency. Furthermore we would like to extend our gratitude to Larry Kester at the DPW for providing us with information regarding the streetlamps maintenance process.

Thank you to Dave Fredericks for his assistance throughout the project. We greatly appreciate your teachings about company workflow and practical engineering to better understand the resolution of an issue. We would also like to thank Jason Bridges for his assistance with the promoting of our project along with his expertise on the creation and managing of a website.

In addition, we would like to thank Charles Walters, Melissa Philbrick, Rachel Hobart, Dr. Michael West, Dr. Sarah Oktay, Elizabeth Gibson, John Smith, Kara Buzanoski, and all the other individuals for allowing us to interview them for our project. The Nantucket Town Association for allowing us to present at their weekly meeting; ReMain Nantucket for sponsoring a trip for the WPI students to explore more of Nantucket; Maria Mitchell Association, specifically Andrew Mckenna-Foster, for supplying housing for our seven weeks on the island and Harvey Young from Young's Bicycle Shop for providing bicycles for all the WPI students throughout the duration of our project work as we are very appreciative.

Finally, we would like to thank the residents of Nantucket for welcoming us on the island for our project and to those that provided feedback through our surveys.

Executive Summary

Background and Methods:

Across the United States, the cost of electricity is rising. Nantucket has some of the highest electricity costs in the country because electricity is imported from the mainland via two undersea cables. With the influx of population and increased energy usage during the summer tourist season, the installation of a third cable is a distinct possibility which would cost a significant amount of money for the Town. Communities across the United States have been implementing energy efficiency programs to try to reduce energy consumption and costs. In Nantucket, the municipal government's goal is to lower the energy usage on the island to reduce costs and forestall the installation of a third National Grid transmission cable to supply electricity. The Town of Nantucket established the Energy Office in 2011 to facilitate this effort.

As part of this ongoing effort, the Energy Office solicited the help of our team to evaluate whether light-emitting diode (LED) streetlamps were a desirable option to reduce energy consumption, maintenance costs, and improve aesthetic appeal of the Town. There are nearly 200 unmetered, Town-owned, decorative streetlamps in Nantucket. Most of the decorative streetlamps are located in the historic core districts of downtown Nantucket and Siasconset and are designed to mimic antique lights consistent with Nantucket's historic past. Although many people in town like the historic appearance of the streetlamps and the warm light they cast, the streetlamps have suffered significant neglect in recent years due to confusion about maintenance responsibilities and poor maintenance records.

The goal of our project was to create a database of the streetlamps to serve as the basis for an improved maintenance program and to evaluate the feasibility of retrofitting the lights with LEDs. The Nantucket Energy Office recruited three LED retrofit companies (Amerlux, LED Conversions, and PennGlobe) to install LED lights in selected streetlamps as part of a pilot project for the evaluation. To achieve our goal, we identified four objectives:

Objective 1: Develop a user-friendly streetlamps database to enhance operations and maintenance.

Our first objective was to develop a database for the streetlamp inventory in order to have a record of information on each of the nearly 200 Town-owned streetlamps. Utilizing an iPad

with the Form Connect Pro application we inventoried the conditions and specifications of each streetlamp before complying data into a Google Spreadsheet in one centralized location.

Objective 2: Create an interactive map of streetlamp locations for the public and officials to utilize for reporting issues.

The second objective was to create an interactive map for the public to identify the problematic streetlamps and inform the officials about the issues. We plotted the streetlamp locations on Google My Maps that could be found on the Town website with a link to the reporting form, along with additional information for the public to access.

Objective 3: Evaluate public and stakeholder opinions on the pilot installation of LED streetlamps at selected locations.

The team's third objective was to evaluate the opinions regarding the LED pilot retrofits installed within nine streetlamps through different types of surveys and interviews of stakeholders. We conducted three types of surveys, in-person, online, and QR code, to gauge the public's feedback on the different options of retrofit pilot kits and overall streetlamp conditions. Key stakeholders were identified and interviewed on their opinions pertaining to the possibility of an LED conversion.

Objective 4: Analyze the economic costs and benefits of replacing the existing streetlamps in the historic district with LEDs.

Our final objective was to calculate the total cost for each retrofit kit, including all aspects for the complete conversion process, to determine the best option for the town. Using information from representatives of National Grid and each pilot LED retrofit company, Amerlux, LED Conversions, and PennGlobe, we calculated the overall conversion cost, reduced tariff rate for LED lights, and payback period for each scenario.

Results and Findings:

Our inventory revealed that there are actually 194 streetlamps in total, rather than the presumed 199 based on prior records. Of the existing 194 streetlamps, six were missing streetlamp fixtures and 23 had various functional issues at the time of our research. To enhance

future maintenance efforts, we created a maintenance record as part of the streetlamp database, along with a workflow process to track the history of repairs.

The interactive map showed the location of the streetlamps and provided a reporting form for the public to notify maintenance officials of problems. The team established a flowchart to illustrate how the appropriate officials would be alerted about the reported issue and the boundary of their responsibilities throughout the reporting process. We also created a manual to show how the inventory database and interactive map were updated accordingly.

We received 126 responses on the LED pilot locations and the general maintenance of the streetlamps from our survey methods. Overall 74% of respondents believed that the LED retrofit was appropriate for the historic downtown area. In comparison with the existing lighting, three-fourth of the respondents indicated they preferred the brightness of LEDs. Ninety percent of respondents indicated they would support an LED conversion with the positive benefits of decreased energy usage and reduced required maintenance.

The team calculated the costs associated with a complete conversion for each specified pilot company. In addition, the projected savings associated with an LED conversion for the Town of Nantucket was determined and a variety of estimated payback periods were presented as examples. However, there was uncertainty in the utilization of the annual maintenance cost for the streetlamps due to lack of records of the current costs and the unknown maintenance required for LEDs. Therefore, the Town should look further into the overall economic of an LED conversion.

Recommendations:

Based on our research and findings we make seven recommendations to the Town of Nantucket.

Recommendation 1: The inventory database, interactive map, streetlamp issue reporting form, and maintenance form should be maintained and updated by one individual in the town.

One individual should have the responsibility to update the inventory database, interactive map, and maintenance form to reduce the chances of the systems not being updated

properly. We recommend that the town officials involved with the decorative streetlamps should appoint a person as the Town Streetlamp Administrator.

Recommendation 2: The Town should define a clear chain of communication for the process of maintaining the streetlamps and responding to complaints.

We recommend that the Town should define a chain of communication that would prevent confusion among the parties involved when an issue with the streetlamp is reported. Each individual party should have a defined responsibility to prevent any detail or action from being overlooked or neglected. This would allow the whole to work in an orderly fashion to efficiently fix safety and other concerns in a timely and cost-effective fashion.

Recommendation 3: The Town should explore ways to upgrade and improve the streetlamp database to address current limitations.

Due to limitations with the software used for both the inventory and map, we recommend that the limitations be resolved with future upgrades to the software. The inventory database and interactive map should be linked for automatic updating. Dropdown menus should be created for the data included on Google My Maps to update the map easily to avoid human error. When a reporting form is submitted, the current status and icon on the interactive map should automatically change. The interactive map should also be upgraded and improved to incorporate extended features for official purposes, such as color coding for specific groups.

Recommendation 4: The Town should improve the conditions of the streetlamps through a scheduled maintenance plan and install more streetlamps to increase the amount of lighting in the downtown area.

The team recommends that the Town create a biannual scheduled maintenance plan for the decorative streetlamps and install more streetlamps in areas identified as inadequately lit. The Department of Public Works (DPW) should take more responsibility in maintaining the structural repairs that do not have to be addressed by an electrician or National Grid. Additional streetlamps should be installed in areas that are lacking street lighting and ambient light from the surrounding businesses. With the addition of new streetlamps to the inventory, the Town should

determine the type of streetlamp fixture and other components that should be the standard for installation.

Recommendation 5: The Town should focus on educating the public on the technology behind LEDs.

Since there is still substantial public misunderstanding about LED technologies, the Town should implement a thorough public outreach effort in advance of implementing a full conversion of the streetlamps to LEDs.

Recommendation 6: The Town of Nantucket should expand upon our research in considering an LED conversion.

The Town should go through with the process of an LED conversion for the decorative streetlamps after further investigation. From the surveys it was apparent that the public was accepting of the possibility of converting the HPS bulbs to LED retrofits to gain the benefits of reduced maintenance and decreased energy usage while preserving the historic appeal of the Town with the warm color temperature. However, the Town should continue gaining public feedback on the LEDs and look further into the economics revolving around the change from the current lighting to LEDs.

Recommendation 7: If the Town of Nantucket implements an LED Conversion, we recommend the 2400 K retrofit kit supplied by Amerlux.

The team recommends the 2400 K retrofit kit from Amerlux for a possible LED conversion. From public input, we determined the public preferred the warmer color of Amerlux's custom made LED for Nantucket.

Authorship

Although each section was written by a primary author as indicated below, the report in its entirety was edited and reviewed by all authors in collaboration.

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Chapter 1: Introduction

Across the United States, the cost of electricity is rising. The average price of electricity has increased from eight cents per kilowatt-hour in 2003 to well above twelve cents per kilowatt-hour in 2014 (EIA, 2014). Nantucket has some of the highest electricity costs in the country because electricity is imported from the mainland via two undersea cables. The island installed the first cable in 1996 when transitioning from the Electro-Motive diesel power plant. The second cable was installed, in 2006, to meet growing demand and provide increased security of supply (National Grid, 2014). With the influx of population and increased energy usage during the summer tourist season, the installation of a third cable is a distinct possibility. The peak energy load of the island in 2013 was increased by 12.5% from the previous high in 2012. If the projections hold true, by 2023 a third cable may be needed to widen the gap between the peak demand and electricity supplied to the island. . This third cable could cost in excess of $80 million (George Aronson and Lauren Sinatra, memorandum to Gregg Tivnan, May 21, 2014).

Communities across the United States have been implementing energy efficiency programs to try to reduce energy consumption and costs. Massachusetts has adopted energy efficient codes and programs such as MassSAVE and the Green Communities Act. In Nantucket, the municipal government's goal is to lower the energy usage on the island to reduce costs and forestall the installation of a third National Grid transmission cable to supply electricity. The Town of Nantucket established the Energy Office in 2011 to facilitate this effort. The Energy Office is responsible for the management and implementation of a variety of programs, activities, and outreach to encourage greater efficiency in the use of energy in general and electricity in particular ("Energy Efficiency," n.d.).

As part of this ongoing effort, the Energy Office hoped to evaluate whether light-emitting diode (LED) streetlamps were a desirable option to reduce energy consumption, maintenance costs, and improve aesthetic appeal of the Town. LED lights have recently expanded to a variety of residential, commercial, and industrial uses, including outdoor lighting. As LED lights gain popularity, several communities are planning to implement LED streetlights and others have already effected these changes to decrease the financial burden of the cities and towns from maintenance costs and electricity use, which are lower when switched to LEDs. Most of these

efforts are still in the pilot process to evaluate LED streetlight performance and public opinions before communities move to full-scale adoption. As a result, there is relatively little information or data on the costs and benefits of LED streetlights. Even fewer communities defined as historic districts have implemented LED street lighting.

The main goal of the project was to evaluate the feasibility and desirability of implementing LED retrofit kits in the Town's decorative streetlamps, located primarily in Nantucket's historic core in the downtown area and Siaconset. The first and second objectives were to develop a single, concise, and complete database and interactive map of the streetlamps for the Town to utilize. Interviews were conducted to gather information about the stakeholders' preferences in regards to the design, content, and maintenance of a comprehensive database. The team also created an interactive map so that the residents could alert the officials about streetlamp issues.

The third objective was to evaluate public and stakeholders' opinions about the pilot installation of LED retrofits in nine of the decorative streetlamps in the downtown area. We identified and interviewed stakeholders and surveyed pedestrians, town employees, and business owners in the historic core district to gather their opinions. The fourth objective was to conduct an economic analysis assessing the costs and benefits under different assumptions. This analysis incorporated the initial installation costs, avoided operational and maintenance costs, payback periods, and the incentives from National Grid. Even if the public and stakeholders were in favor of the LED lights, the Town governance must determine whether the full implementation would be an economically feasible option. The information gathered from the objectives was used to determine if LED streetlights should be installed throughout the entire district.

Chapter 2: Background

2.1 Introduction

This chapter discusses the energy consumption, technology behind light emitting diodes, LED implementations in other cities, and public concerns of the implementation of LED streetlamps. There is a concern about a rise in energy cost as the years progress and the risk of requiring a third transmission cable from the mainland. To maximize the energy efficiency and minimize the cost of operation and maintenance, the Town of Nantucket will explore the possible option of implementing LEDs in the streetlamps.

2.2 Electricity Use and Efficiency Programs in Massachusetts

The U.S. Energy Information Administration has plotted energy consumption in the United States from 2012 to 2015, as seen in Figure 1 below. Electricity use in the United States typically peaks in the summer and again in winter, but the overall consumption has remained relatively consistent in the past three years (EIA, 2014). This may raise the question to why there is a desire to reduce energy usage.

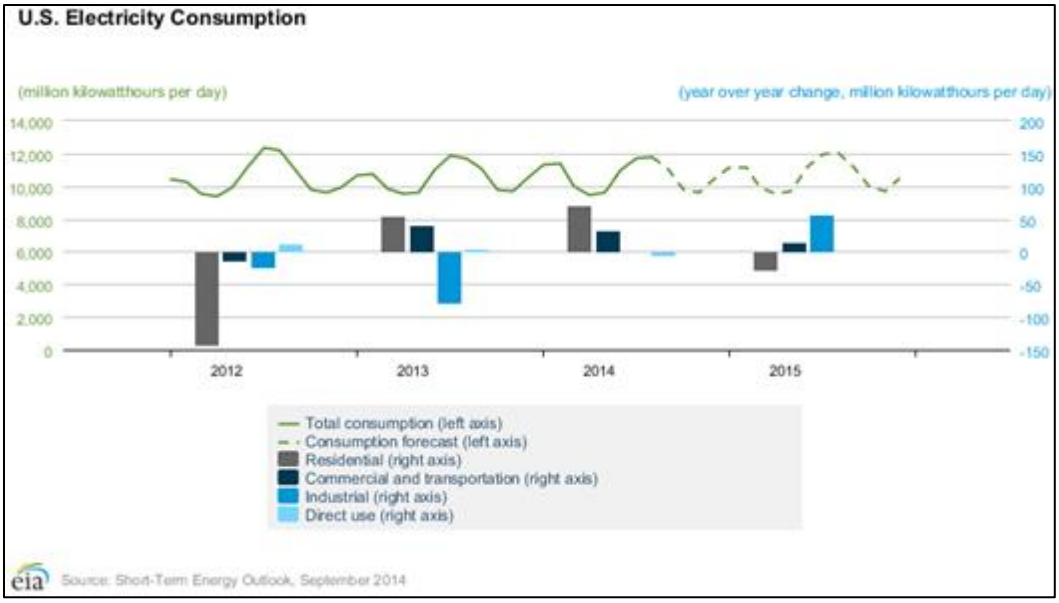


Figure 1 Short-Term Energy Outlook (EIA, 2014)

Figure 2 below shows the U.S. residential cost of energy in terms of cents per kilowatt-hour. From 2003 to 2014, there is a clearly defined rise in energy prices for residential use from 8 cents per kilowatt-hour to well above 12 cents per kilowatt-hour (EIA, 2014). This rise in energy cost has encouraged many state and local governments to develop policies and programs to reduce their energy usage.

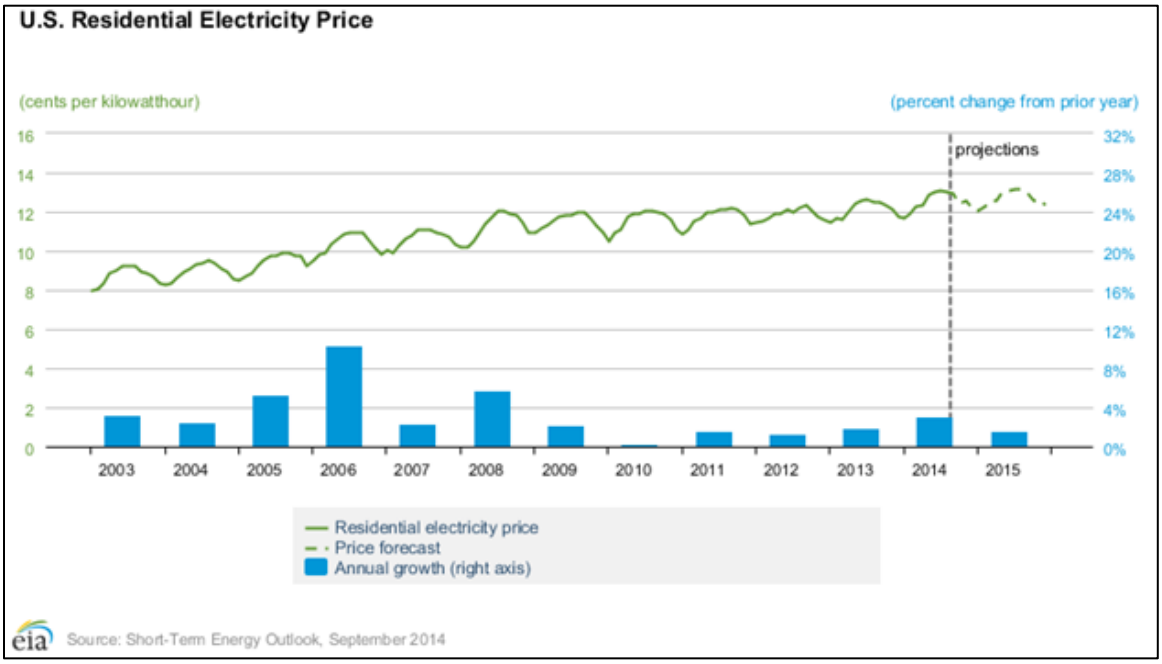


Figure 2 U.S. Residential Electricity Prices (EIA, 2014)

As shown in Figure 3 below, the Northeast has some of the highest electricity rates in the United States. With an electricity cost between 11.61 and 34.07 cents per kilowatt-hour and the growing desire to reduce global warming, it is clear why state and local governments are creating programs to use energy more efficiently. Within recent years Massachusetts has implemented a variety of energy efficient codes and programs to reduce their energy consumption. Many of these programs are increasingly focusing on the use of LED lighting in residential, commercial, and government settings.

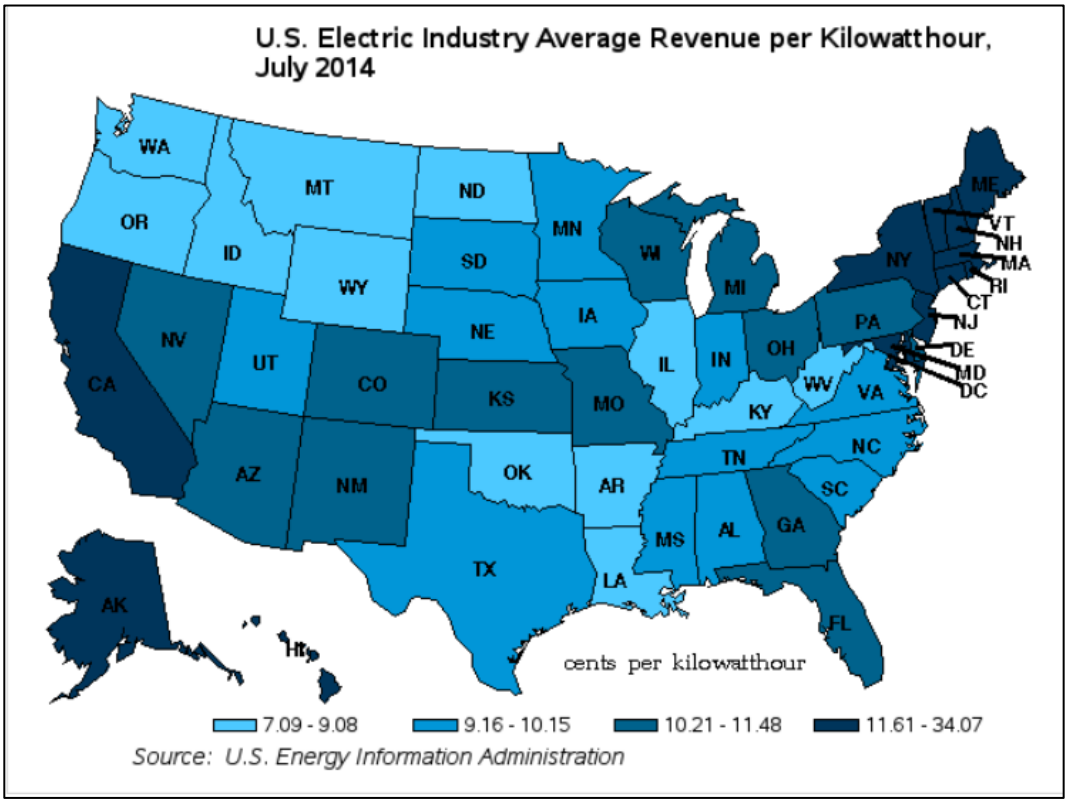


Figure 3 U.S. Electric Industry Average Revenue per Kilowatt-Hour (EIA, 2014)

Multiple organizations offer assistance through funding and incentives in support of energy efficient and environmental projects. The Green Communities Act passed on July 26, 2008, "provides funding to qualifying communities for energy efficiency and conservation projects and alternative or renewable energy source construction, among other project types." (M.J. Bradley & Associates, n.d). Through the Green Communities Act, Wenham received a $248,029 grant to fund a town-wide streetlight conversion to LED, while Watertown obtained a $192,825 grant to implement high efficiency LED streetlights ("Green Communities Designation and Grant Program," 2014). These two communities along with many others in Massachusetts are on the cutting edge of policies to save energy. National Grid also offers services and rebates to encourage people to use environmentally conscious and more efficient technologies in their homes or businesses. The company will send a specialist to the location to do an energy audit and offer helpful tips to reduce the money the individual or organization spends and the energy they use. National Grid offers programs for assisting businesses in saving energy and money by upgrading their lights to LED and installing sensors to turn off the lights when there is no one present in a room (National Grid, n.d.)

Massachusetts's Governor, Deval Patrick, created programs in an effort to reduce the overall energy use in state-owned buildings. Executive Order 484 states "that state agencies shall prioritize practices and programs that address resource use at state facilities, including a reduction in energy consumption." One of the many targets set forth for agency buildings were to reduce energy usage by 35% by the year 2020 (*Executive Order No. 484*, 2007). The Governor encourages widespread installation and use of LED lights rather than conventional lighting to reduce the overall energy consumption.

The American Council for an Energy Efficient Economy (ACEEE) assesses each state of the United States and ranks them according to "energy codes, combined heat and power, state government-LED initiative, appliance standards, and future perspective" ("Massachusetts | ACEEE," 2014). Massachusetts was ranked number one for its LED lighting and energy policies and initiatives in order to reduce the state wide energy use ("Massachusetts | ACEEE," 2014).

2.3 Energy Use and Efficiency Programs in Nantucket

Nantucket experiences an influx of population during the summer tourist season that requires a demand of energy that could potentially exceed the current amount supplied to the island. In 1996, Nantucket upgraded from generating energy on island with an Electro-Motive diesel power plant to a National Grid transmission cable connected to the mainland. This cable was installed because the demand for electricity on the island had increased rapidly to the point where the demand threatened to exceed the supply. National Grid then installed a second cable in 2006 to ensure an adequate, uninterrupted energy supply sufficient to meet growing peak demand (National Grid, 2014). The summer peak demand for power, however, continues to grow and Figure 4 illustrates how the projected energy demand for the island is now approaching the capacity of the two cables.[1] The energy load on the island on July 19, 2013 was more than 12% higher than the previous high in 2012 (George Aronson and Lauren Sinatra, memorandum to Gregg Tivnan, May 21, 2014). Two cables are currently able to meet peak demand, but National Grid and the Town of Nantucket are concerned that they may need a third cable as 'insurance' for summer periods should one cable become disabled.

[1] This graph was obtained from a National Grid presentation on September 22, 2014 titled "Working Together toward a Sound Energy Future: Long Term Energy & Sustainability Planning on Nantucket."

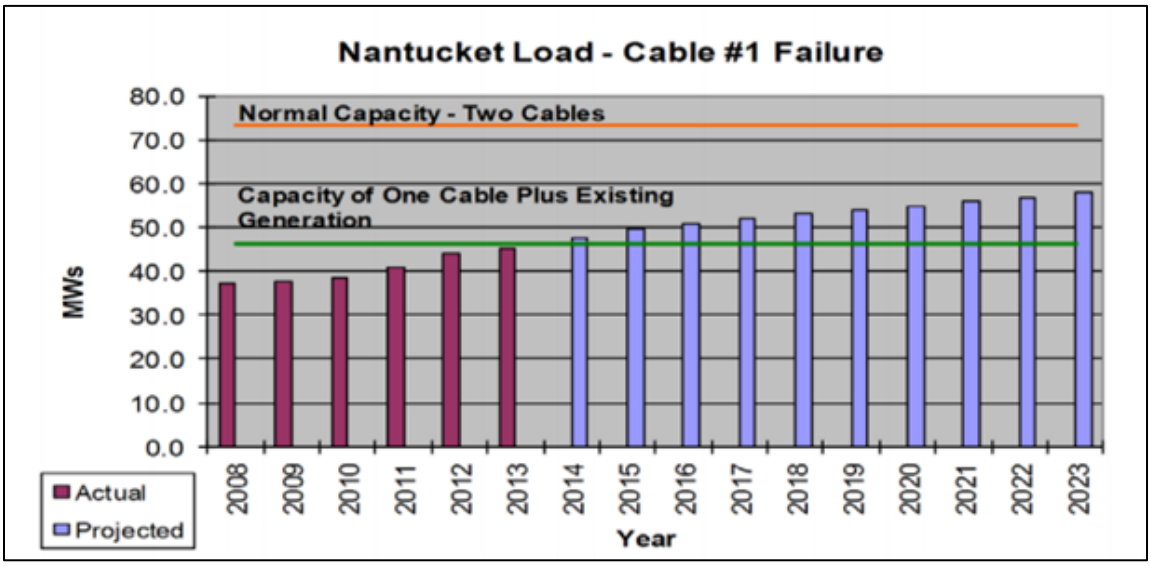


Figure 4 Projected Energy Demand

The cost of energy imported from the mainland is high because of surcharges imposed by National Grid to pay for the cables. A surcharge on electricity bills was used to pay off the capital cost of the first cable and is still being levied in order to pay the remaining costs of the second cable. The basic service supply prices for energy from National Grid are based on rates for the Southeastern MA (SEMA) power zone of Massachusetts. However, Nantucket has an additional cable surcharge that changes price between the summer and winter. In 2013, the regular residential rate (R1) for Nantucket included a 2.190 cent per kilowatt-hour surcharge for the summer and a 1.254 cent per kilowatt-hour surcharge for winter (National Grid, 2013). The high cost of imported energy and seasonal fluctuation of population that increases the demand of energy are motivators for energy efficiency and conservation programs to stall the potential need for a third cable.

The Town of Nantucket spent roughly $3 million on electricity and liquid fuels for their various municipal buildings, vehicles, and decorative streetlamps in the 2012 fiscal year ("History of Energy on Nantucket," n.d.). In Figure 5, the top energy consuming municipal facilities in Nantucket are identified, including the Nantucket High School, Nantucket Memorial Airport, and the Nantucket Town Building (Dery, George, McKenna, & Rice, 2013).

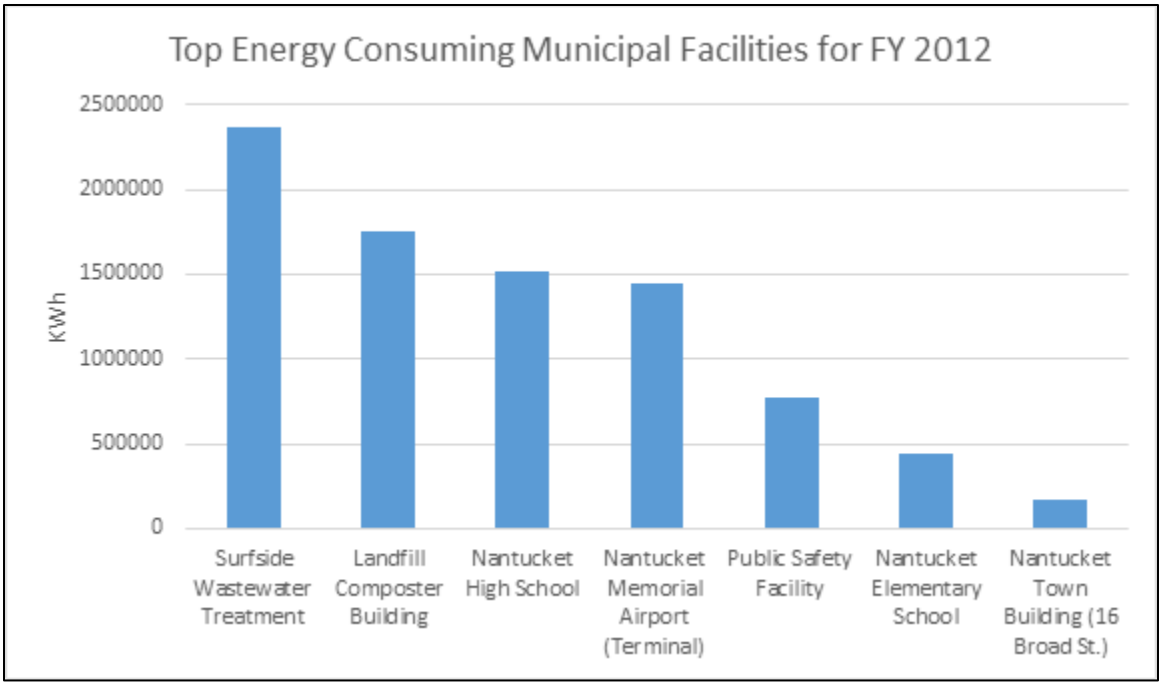


Figure 5 Top Energy Consuming Municipal Facilities (Dery, George, McKenna, & Rice, 2013)

In response, the Town of Nantucket has implemented a variety of programs and efforts to reduce energy consumption on the island, including the creation of the Energy Office and the participation in MassSAVE programs. The Energy Office was founded in 2011 with the purpose of managing and promoting energy efficiency on the island to combat the increasing energy usage. A major initiative of the office is to focus on energy efficiency. Energy efficiency is the ability to continue performing a daily task or function using alternatives that lower overall energy use ("Energy Efficiency," n.d.).

The Energy Office's projects focus on implementing and evaluating alternative technology for the reduction of energy usage. The office organizes energy assessments for residents and businesses offered through the MassSAVE Program. Through sponsoring WPI Nantucket Project Center projects, the Nantucket Energy Office conducted an evaluation on municipal employees' awareness of energy efficiency, emphasizing the use of the SEE the Light Toolkit for energy conservation. In addition, to track the energy usage of the Town facilities, which are the leading consumer of energy on Nantucket, the Energy Office implemented the MassEnergyInsight tool. The overall result of the efforts of the Energy Office is reflected in the 7% electricity use reduction in the Town of Nantucket in the 2013 fiscal year compared to the

2012 fiscal year (George Aronson and Lauren Sinatra, memorandum to Gregg Tivnan, May 21, 2014).

The municipal government of Nantucket understands the need to lead by example in the road to energy reduction on the island, specifically in the municipal facilities where lighting audits are performed. The Massachusetts Department of Energy Resources (DOER) Lead by Example Program secured 1,032 free LED and compact fluorescent lights for many of the Nantucket town facilities. The Energy Office estimates the projected savings for the town from installing these lights will be approximately 70,500 kilowatt-hour and $10,500 per year at current rates. In July 2014, the island of Nantucket participated in their first MassSAVE Home Energy Assessment Week. MassSAVE provides incentives and knowledge to businesses and home owners on how to manage their energy costs. The program installed 3,121 LED lights in residential homes on Nantucket for no cost ("Town of Nantucket Energy Office," 2014). These programs aim to reduce energy usage on the island by the municipal government, residents, and small businesses.

The Town of Nantucket Energy Office wants to further decrease the municipal energy consumption by evaluating the possibility of implementing LED light retrofits in the nearly 200 decorative streetlamps in the core historic districts in the Town and Siasconset. The general location of the historic downtown area encompasses the streets within the outline illustrated in Figure 6 (Town of Nantucket, n.d.).

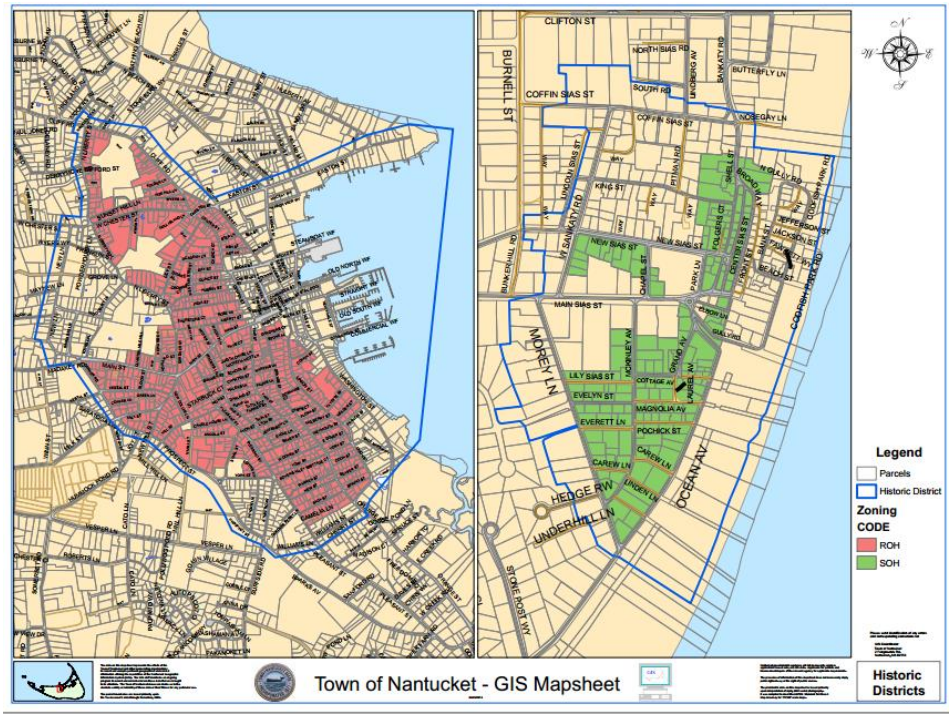


Figure 6 Outlined Historic Districts (Town of Nantucket, n.d.)

In addition to these Town-owned streetlamps, there are also several privately-owned decorative streetlamps of a similar design in the downtown historic area. The history of the decorative streetlamps in Nantucket traces back to the 19th century after the adoption of streetlamps in the 18th century by major American cities such as Boston. Edouard Stackpole (as cited in Hubbs, 2002) described the development of the Nantucket streetlamps from lanterns placed outside residents' doors to the installation of street poles that used electric light.

The historic core in Town and Siasconset includes a mix of two styles of fixture: The *Boulevard* (Figure 7a) has a globe enclosure and the *Philadelphia* (Figure 7b) has a triangular enclosure (PennGlobe, 2014). The streetlamp fixtures were purchased from PennGlobe by the Town of Nantucket. There are slight variations in the details of the fixtures: for example some of the Boulevard fixtures have translucent tops while others are opaque. In addition to the variation in fixtures, the streetlamp poles comprise different materials, including cast metal, wood, and fiberglass depending on when they were installed or replaced. Updating the streetlamps over the years has resulted in a random mix of fixtures and materials in the historic core as lighting technology, designs, and purchasing decisions have changed according to a report by Edouard Stackpole (as cited in Hubbs, 2002).

Figure 7 (a) Boulevard Fixture Style (b) Philadelphia Fixture Style

In 2006, the Town of Nantucket took ownership of the decorative streetlamps from National Grid and became responsible for their maintenance and repair. At that time, the streetlamps were upgraded to a different tariff rate from National Grid to reflect the town ownership of the streetlamps. The tariff rate is the set price that the Town pays National Grid for electricity to the lamps based on the estimated kilowatt hours expected. The streetlamps are unmetered and have a tariff rate of S-3B (Elizabeth Gibson, memorandum to Wendy B. Watts, June 12, 2006). Under this tariff rate, the Town is responsible for maintaining and replacing the posts if they are damaged, for example by vehicles. The Town contracts with Ryder Electric to maintain the physical posts and fixtures. In contrast, National Grid is responsible for supplying the electricity to the lights, maintaining the underground and overhead cables that feed the lights, and repairing broken light bulbs and photocells.

Lauren Sinatra, Energy Coordinator, believes that replacing the existing streetlamps with LED alternatives could save the municipal government and taxpayers' money by reducing overall energy consumption and maintenance costs. Many people are concerned about the real cost savings and the quality of the light LEDs may cast, especially within the historic district. In the next sections, we review the background on LEDs and some of the studies that have examined the use of LEDs in streetlights.

2.4 History and Development of LEDs (Light Emitting Diodes)

LED lights are only now becoming popular in residential and commercial markets, but they have a history that dates back to the early 20th century. In 1907, Henry Round discovered the basic phenomenon when he wedged a silicon carbide crystal between two wires and witnessed it emit a light at ten volts. It was not until 1990, however, when Sir Richard Friend from England developed an LED based on polymers. The molecular orientation in the polymer forced the electrons in the electric current to react in a uniform fashion, which provided consistency in releasing light (Kramer, 2008).

Current LEDs, also referred to as solid-state lighting, are semiconductor devices. Theoretically, LEDs can produce any color due to different combinations of the basic red, green, and blue colors that were developed. However, if the mixing ratio of the RGB-LEDs varies in one color, it can cascade to a considerable change on the hue of the light, especially in the color white. Even after the white LED is created, the challenge is to maintain the same white color LED throughout its lifetime; this is due to changes in the individual RGB-LED intensity, time, and lumen output due to temperature. Blue LED light output decreases by 2% for every $10^{o}C$ increment, while the green and red light outputs decrease by 5% and 10% respectively. The variation in the light output shifts the LED white color towards the blue-green spectrum since the red LED reduction in light output is the highest (Muthu, Schuurmans, & Pashley, 2002). This phenomenon may explain why LEDs are often criticized by consumers for the cold, blue light they generate ("Case Study, Ann Arbor", 2011).

To describe the variation of the white light, William Kelvin introduced color temperature in the late 1800s after he observed a wedge of carbon changing color when heated. The color ranged from dark red at low temperatures to blue-white at high temperatures. The Kelvin system became the official measuring unit for color temperature. Most streetlights are high intensity discharges (HID) that have color temperatures around 2200 K as shown in Figure 8. The HID color temperature has a warmer color compared to other sources of light, such as incandescent, halogen, and warm LED (Seesmart Inc., 2010). The LED lights that are being piloted on the island of Nantucket are in the 2200 K to 4000 K range and have warmer colors than many of the previous LED installations that have raised public objections elsewhere in the US.

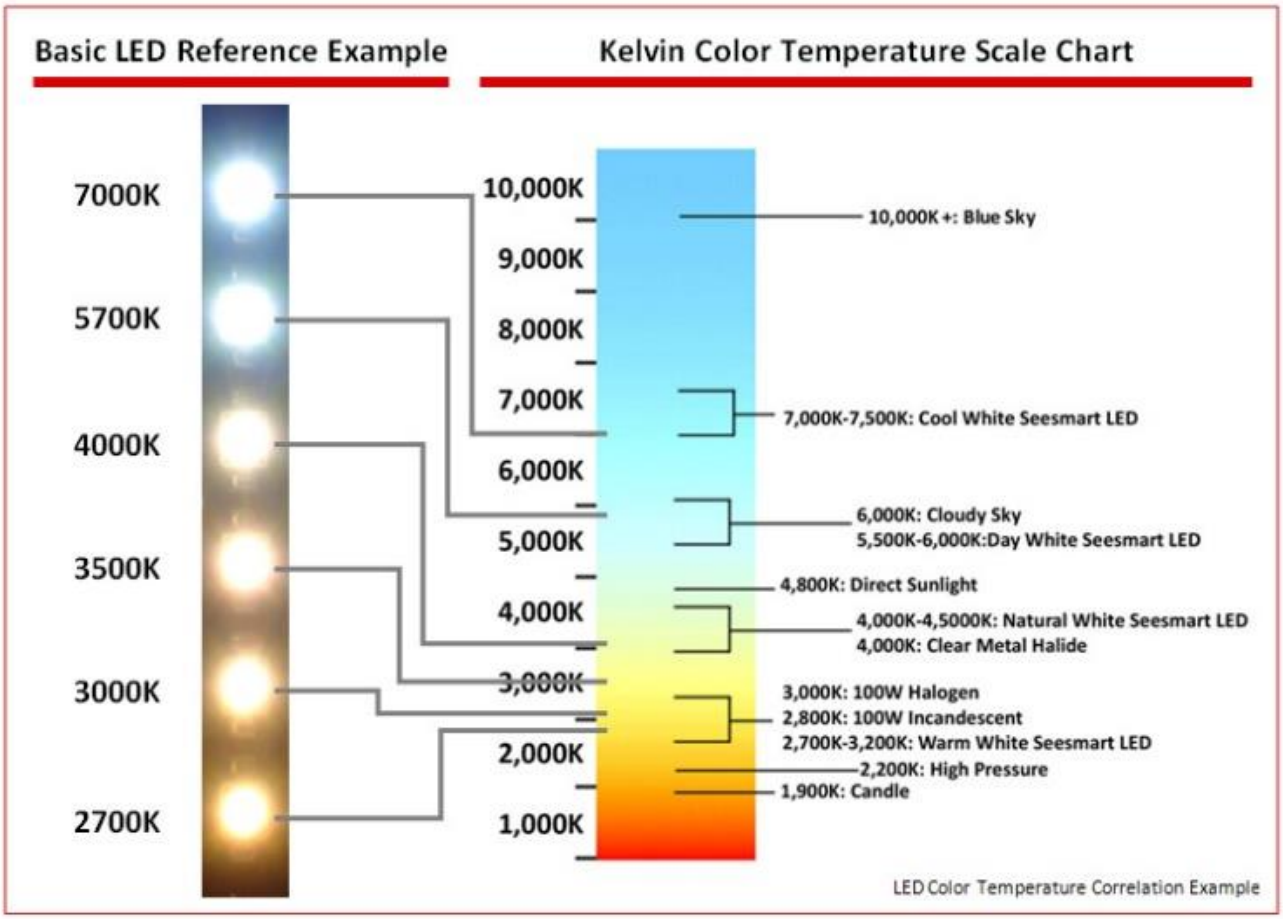


Figure 8 Color Temperature Scale (Seesart Inc., 2010)

Besides the variation of colors, LED lights are also unique due to their heat management system. LEDs do not emit heat like traditional lights because the heat produced by the LEDs is transferred to a heat sink. The lower operating temperatures minimize damage and result in much longer lifespans for LEDs compared with alternative lighting technologies ("Learn About LEDs," n.d.). The lifespan of a standard LED is more than 50,000 hours, while fluorescent lights can last for 5,000 hours and incandescent lights typically fail after roughly 500 hours. Encapsulants, usually made from a clear polymer, surround the LEDs to provide protection and a stable environment (Figure 9). The encapsulants protect the LEDs from weather and unforeseen chemical reactions, and control humidity that may result from interactions with the environment (Schubert, Gessmann, & Kim, 2005).

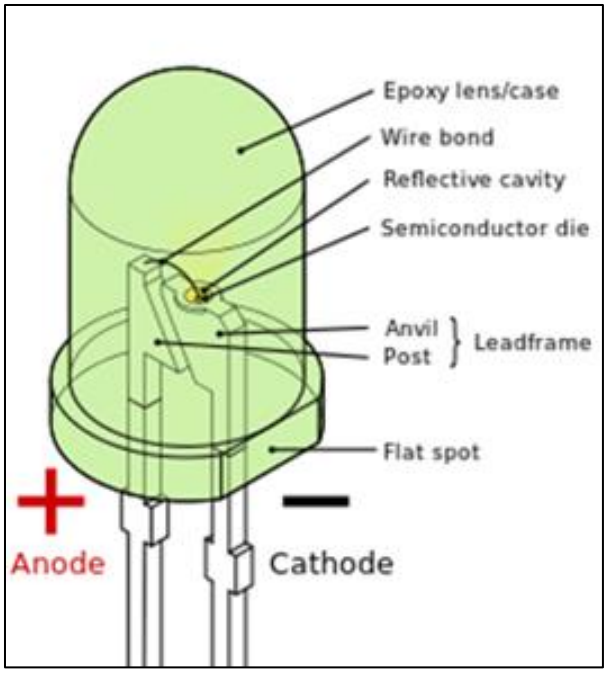


Figure 9 LED with the Encapsulant (Wikipedia, 2009)

LED lights can provide as much or more light than standard incandescent lights while using less energy. For example, a 15 watt LED produces the same amount of light but uses 85% less energy than a 100 watt incandescent lamp (Khan, 2011). Currently, LEDs provide 83 lumens per watt compared with 67 lumens per watt for compact fluorescent lights (CFL) and 16 to 20 lumens per watt for incandescent bulbs.[2] As shown in Figure 10, the efficiency of LEDs is expected to improve substantially in the coming years. LEDs may produce 150 lumens per watt by 2020, while the efficiencies of conventional fluorescent and incandescent lights are likely to remain flat (Comstock, 2014). Compared to other types of lighting sources, LEDs have the lowest electricity consumption relative to the lumens they produces, as shown in Figure 11.

[2] Lumens are the measurement for light intensity to compare different light sources.

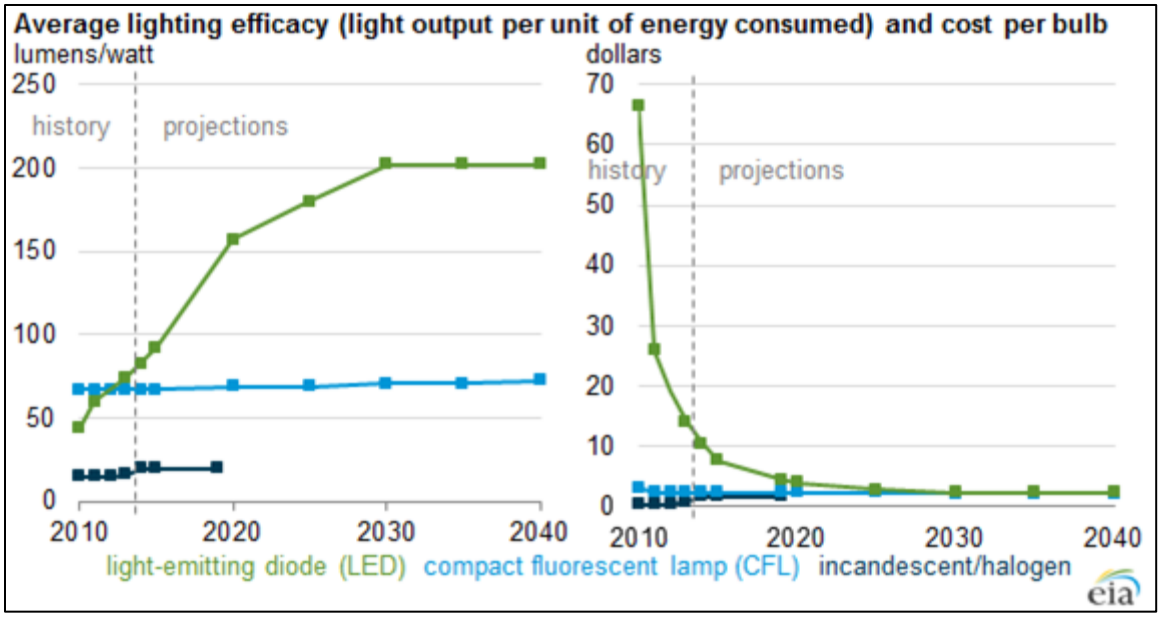


Figure 10 Annual Energy Outlook 2014 Early Release (Comstock, 2014)

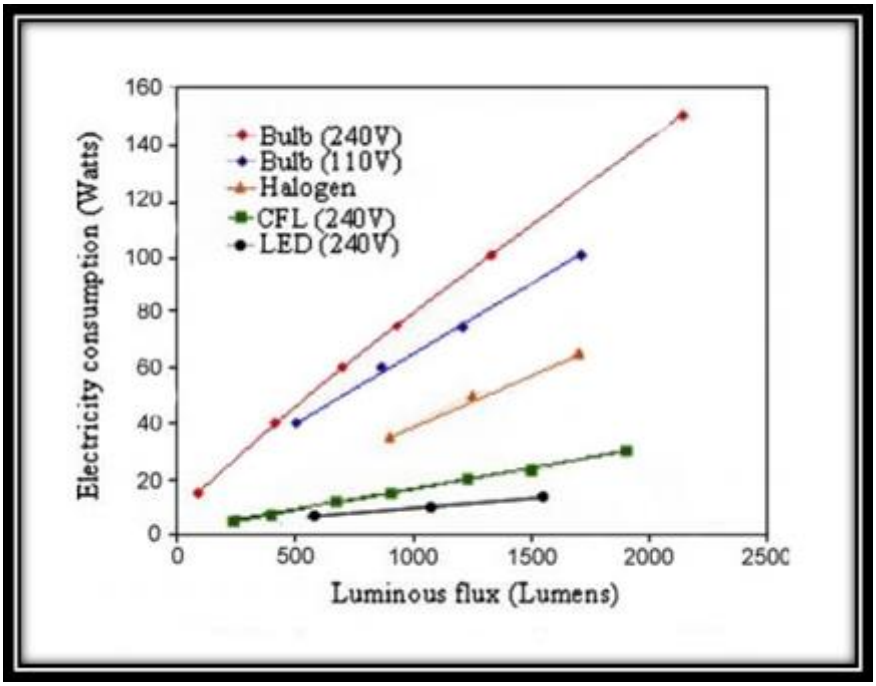


Figure 11 LED Luminous Flux as Function of Rated Power (Comstock, 2014)

The prices for LED lights are higher than the equivalent CFL and incandescent lights but costs are expected to fall dramatically (Figure 10) as the technology advances and the consumer market grows. As of 2014, the capital cost of LED bulbs is around $10 to $15 while the cost for the conventional lights is less than $5. This does not factor in the cost of fixtures that are used for

retrofitting LEDs, which can vary greatly in price (Comstock, 2014). Even though the cost is greater than other lights, the benefits of LED lights outweigh the expense, as shown in Table 1.

***Data from (Khan, 2011)**

	Incandescent Bulb	**CFL**	**LED**
Initial Cost ($)	~1.50	~2.50	~10.00 - 15.00
Power (W)	100*	23*	15*
Efficacy (Lm/W)	16-20	67	83
Lifetime (hours)	500	5,000	50,000

Table 1 Summary of Comparisons among Incandescent, CFL, and LED Lights

2.5 Implementation of LED Streetlights

The majority of streetlights in towns and cities are high pressure sodium (HPS), a type of high intensity discharge (HID) lamp. HID lights consist of a tube filled with vaporized metal that a current runs through at extreme temperatures and pressures to radiate light. HPS lights are a popular option for outdoor lighting due to their high lumen production, energy efficiency, long lifespan (10,000 to 24,000 hours), and immunity to outdoor temperatures. In 2004, LED and HID streetlights were equal in efficiency, but LEDs have become much more energy efficient and will continue to do so (Sullivan, 2004). As mentioned above, their lifespans are approximately 50,000 hours, which reduces long-term maintenance costs since bulbs do not have to be replaced as frequently (Schubert, Gessmann, & Kim, 2005). LEDs also function more effectively in cooler climates where they can be activated quickly with little delay time to provide general visibility for the surroundings. The limitation of current LED streetlights is the initial installation costs, especially since HID bulbs cannot merely be replaced by LEDs (Sullivan, 2004). One must consider the cost to remove the old conventional light fixtures and install the new LED lights. The poles, wires, or fixtures often need to be modified or replaced to be compatible with the LEDs (Ylinen, Tähkämö, Puolakka, & Halonen, 2013). Nevertheless, the LED technology is expected to improve dramatically over time with increases in efficiency that will substantially

reduce operating costs and payback periods. As the technology evolves and LEDs are more widely adopted the initial costs of the bulbs and fixtures will likely decline (Sullivan, 2004).

With LED lights gaining popularity, many communities and cities are starting to explore the use of LEDs in traffic lights, streetlights, and outdoor lighting to save maintenance and operating costs. LED streetlights use roughly one third to one half of the energy an HID would consume. Since LED lifespan is two to five times the HID lifetime, the cost and time spent on maintenance for LEDs would be reduced. Using LEDs for streetlights and other outdoor lighting may be especially appropriate for islands or mountainous areas because it can be costly for those regions to hire maintenance specialists (Yuichi & Toshiaki, 2008).

Although LED lights are more energy efficient than the traditional lights, one must also evaluate whether they are a feasible option for implementation. The research should focus on the current and projected price, the maintenance and shipping costs, and the payback period. Some towns are setting up LED pilots to evaluate how the lights operate in different settings and how the public reacts. Many of these case studies are still in progress so the data on cost, performance, and public opinion are still being evaluated.

Ann Arbor, Michigan placed pilots in 2006 to test the performance of LEDs in general lighting. The town hoped the pilots would expand to a full implementation to reduce the funding spent on streetlights annually, which is $1.28 million. The city installed two types of LED fixtures called the test globe and the cobrahead as shown in Figure 12; the comparison between the two fixtures is shown in Table 2. The test globe is a decorative light, similar to the ones in downtown Nantucket, and the cobrahead fixture is a streetlight style typically used on many roadways.

Figure 12 Test Globe (left) and Cobrahead (right) (Relume Technologies, 2011)

	Test Globe Fixture	**Cobrahead Fixture**
Energy Consumption (% Traditional Light)	50%	80%
Power (W)	48	50-80
Original lights Power (W)	100	250
CO_2 Emissions per light	203 kg	781 kg

Table 2 Comparison Between Test Globe and Cobrahead Fixtures

The two fixtures were estimated to use 50% to 80% of the energy traditional lights would consume. The decorative globe lights with LEDs use 48 watts that would last around ten years compared to the conventional lights that use 100 watts and last for two years. The cobrahead ranges from 50 to 80 watts compared to the original light with 250 watts. The city wanted to evaluate on three factors: light output, heat management, and public opinion. Light output examines how the light will provide visibility and aesthetics, heat management will affect the LEDs lifespan, and the public responses to the pilots will determine the expansion of LED installments throughout the city. There were 83 responses from the public with 81 of them on the positive note. The residents noticed that there was no light trespassing into their houses and

yards. However, one negative comment noted that "the light was too harsh". The LED streetlights were estimated to cost $472 each with $100 in savings annually per fixture with a payback period of 4.7 years. From the environmental aspect, CO_2 emission would reduce by 203 kg per decorative globe and 781 kg per cobrahead yearly. Before Ann Arbor could implement LED lights, they must find funding to pay the high initial cost and seek approval from the energy company, which owns many of the streetlights, for the streetlight tariff ("Case Study, Ann Arbor", 2011).

Other cities in the United States shared a similar experience as Ann Arbor, when they installed LED streetlights into their communities, as shown in Table 3. Cities like Anchorage, Los Angeles, Portland, Sacramento, Seattle, and San Diego started to install the pilots around 2006. They replaced some of their HPS lights with LED streetlights in pilot studies and then estimated costs for full implementation. Depending on the city's size and the number of streetlights, the cost savings varied. For example, San Diego and Anchorage, estimated they would save roughly $254,000 to $360,000 yearly, while a large city like Los Angeles could save as much as $10 million annually ("LED Roadway", 2014; "City of Anchorage", 2013; "City of Los Angeles", 2009). While many cities are projecting cost reductions, Sacramento's cost analysis revealed few savings for the city. Since the city wanted an equivalent of luminosity in the LED streetlights, the benefits did not outweigh the costs (Tuenge, Bryan, & Bisbee, 2011). Five of the seven cities conducted surveys to gather the public opinion on the LED pilots and received positive feedback overall. Very few people were bothered by the LED lights, although these were not mounted in historic districts. Overall, the streetlights decrease CO_2 emissions into the atmosphere, consume roughly 50% of the energy HPS used, and provide more visibility on the streets ("Case Study, Ann Arbor", 2011; "City of Anchorage", 2013). While the initial cost for the lights and installation are high, the payback period is about 5 to 7 years depending on the style of LED fixtures, the tariffs, and the cost for maintaining the lights ("Case Study, Ann Arbor", 2011; "City of Los Angeles", 2009). In the case of Seattle, the city piloted the LED streetlights and decided to fully convert after an overall assessment and the positive public feedback. The 41,000 lights would be changed over the course of 2010 to 2014. When a current light ceases to function, it will be changed to a LED light instead of converting all of the lights at once. After the installation is done, the city is estimated to save $2.4 million annually on operating and maintenance costs (Seattle City Light, n.d.).

Cities	Date	Existing lights	Estimated savings	Public opinions	Benefits
Ann Arbor, Michigan	2006	HID	$100 per fixture	Positive feedback	• Lower CO_2 emissions • ~4.7 years payback
Anchorage, Alaska	2008	HPS	$360,000/year	Positive feedback	• 50% Less energy than HPS
Los Angeles, California	2009	HPS	$10 million/year	N/A	• Reduce 40,500 tons CO_2 per year • 7 years payback
Portland, Oregon	2009	HPS	N/A	Positive feedback	• Provide visibility in the neighborhood
Seattle, Washington	2009	HPS	$2.4 million/year	Positive feedback	• 48%-62% less energy • 7.7 years payback
Sacramento, California	2011	HPS	Benefits did not outweigh costs	N/A	• Energy savings • Analyzed HPS vs LED performance
San Diego, California	2014	HPS	$254,000/year	Positive feedback	• Antique appearance for lamp design

Table 3 LED Case Studies

In 2008, the City of St. Paul reported of spending roughly $3.16 million annually to maintain its 37,000 streetlights. After reviewing case studies from cities like Anchorage, Alaska and Ann Arbor, Michigan, St. Paul intended to adopt LEDs for their streetlights. As shown in Table 4, the city recognized the benefits of reduced maintenance cost, LEDs longer lifespan,

50% decrease in energy consumption, and no mercury present in the light (compared to CFL and HID). They also acknowledged the disadvantages of initial costs. The prior HPS lights cost $70 per bulb with a lifespan of 10,000 to 24,000 hours, while LEDs cost $400 to $500 with a lifespan of 50,000 hours (Havens, 2008).

Advantages	Disadvantages
• Energy Efficient • Low Maintenance Cost • Long Lifespan • Less CO_2 Emissions • Perspective Future Improvements • Operates at Range of Temperatures • Continued Price Decrease • Less Light Spillage	• Initial Cost • Cost of Converting Fixtures, Wires, and Poles • LED Technology and Cost Continuously Changing

Table 4 Advantages and Disadvantages of Implementing LED Lights

The LED prices will drop as the technology improves in the future (Figure 10), but the constant change in cost makes it difficult for towns and cities to decide on when to buy LED lights. The longer they wait the better the cost/benefit ratio will be. These factors encouraged St. Paul to invest $20,000 to research the different options and when to implement them rather than immediately investing in full-scale implementation (Havens, 2008).

2.5.1 Community Concerns

The public has various concerns about street lighting in general and LEDs in particular. From the case studies, public feedback indicates that issues range from light pollution and trespass to light intensity and color to health and environmental concerns. At the same time, surveys also reveal public support for LED conversions.

A prominent concern about LED lighting is the increased potential for light pollution due to the increased intensity of the lighting. Light pollution can be a detrimental side effect of any

outdoor lighting and depends on the intensity of the lighting and the angle of projection in relation to the sky. The most problematic types of light pollution are glare, light trespass, and skyglow. Skyglow is the technical term for light pollution; it is the illumination of the sky by artificial lights (Upgren, 2006). Glare is when light is shone or reflected onto an organism and in turn causes discomfort. And lastly, light trespass involves light being directed into areas it was not intended to touch (Devries, Giambrone, Haring, & Penrose, 2013). Specifically to streetlights, glare and light trespass cause limited visibility and discomfort to a person who is driving or walking by the light source. The negative effects of light pollution can be limited by the implementation of the correct shielding on fixtures to limit the exposed lighting, decreasing the detrimental impacts on the atmosphere and people. Examples of degrees of shielding and outcomes in the night sky are shown in Figure 13 below (Maria Mitchell Association, 2014).

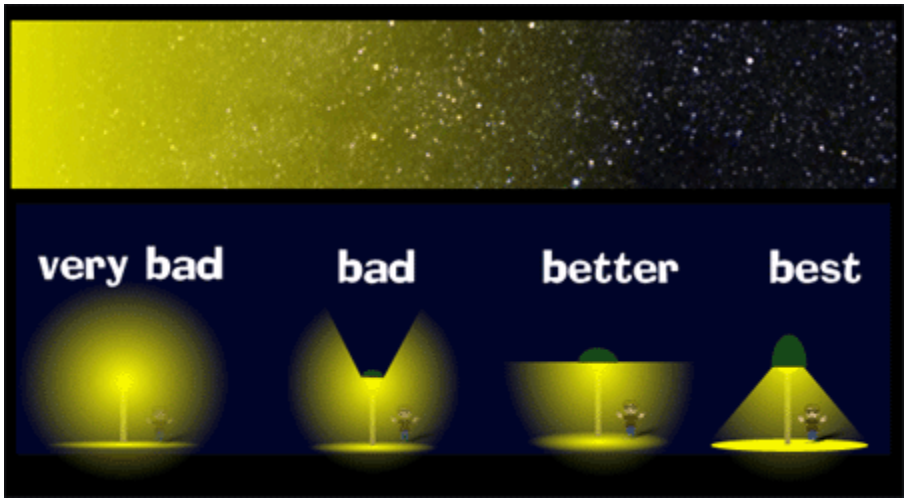


Figure 13 Degrees of Shielding in Light Fixtures (Maria Mitchell Association, 2014)

Another apprehension connected to the conversion of streetlights is sleep disturbance. LED streetlights were employed in the city of Cambridge and were met with concerns from residents claiming that the new blue lights were disturbing their sleep. One resident complained that the more intense lighting was shining into his bedroom window and he highlighted the idea that being exposed to light while sleeping can cause negative health effects. The lighting director of the city of Cambridge claimed to the people that the "levels were way too low to do any negative effects on your biological clock" which was contrary to popular belief of the public (Sotnik, 2014).

The installation of LED streetlights also provides communities with various benefits, one of the most prominent being increased safety. Security guards at the Federal Aviation Administration in New Jersey ranked the new LED lighting above the previous HPS lighting because it provided a higher level of visibility (DOE, 2008). Other positive aspects of LED lighting that have been noted are the visual accessibility and perceived brightness. Residents surveyed in a study commended the softness of the lights and the ability of the streetlights to reflect the natural color of the outdoor environment (Kuhn, Johansson, Laike, & Goven, 2013). In one community in Kolkata, India, the improved visual quality of the LED streetlights is purported to have increased sales at local small businesses and "more than 90% of Kolkata's road and park users find LEDs to be a better lighting option than conventional lights" (The Climate Group, 2013).

A similar LED pilot project was conducted in the city of Seattle with a concurrent survey of the public. Overall, the project found positive feedback from the public which prompted additional installations of LED lights. On the other hand, survey respondents complained of "excessive brightness, increased glare, and the dismal, unwelcoming color of the lights." Figure 14 shows the difference between the previous HPS bulbs and the new LED lights in Seattle (DKS Associates Transportation Solution, 2009).

Figure 14 Before (left) and After (right) Seattle Conversion (Seattle City Light, n.d.)

In San Francisco the Public Utilities Commission found that the public supported LED retrofits because the improved lighting was believed to enhance pedestrian safety (San Francisco Public Utilities Commission, n.d.). In another survey, members of the public approved of the new streetlights' abilities to illuminate areas for prevention of accidents due to stronger light emissions (DOE, 2013).

2.6 Conclusion

Energy use, specifically electricity use, is a major concern to the Town of Nantucket because of the higher than normal cost of energy with the surcharge from the National Grid transmission cable that supplies electricity to the island. In the past, residents of Nantucket have been open to energy efficiency programs conducted by the Town. For example, the Nantucket Energy Office provided LED bulbs with energy assessments of homes, which increased by 600% in participation from the previous year ("Town of Nantucket Energy Office," 2014). Due to the limited budget and a concern for the increasing energy demand, the Town of Nantucket is exploring the option of LED street lighting in their 199 decorative streetlamps in the core historic districts. The public, officials, and others impacted by the installation will have to consider the reliability, cost, and public opinion on the use of LEDs. The Town of Nantucket is examining LED lights in regards to efficiency, cost, and aesthetics before the full implementation of LED streetlamps in the historic district.

Chapter 3: Methodology

The purpose of this project was to evaluate the feasibility and desirability of installing LED street lighting in the historic district of Nantucket. The primary objectives to complete this project were:

- Objective 1: Develop a user-friendly streetlamps database to enhance operations and maintenance.
- Objective 2: Create an interactive map of streetlamp locations for the public and officials to utilize for reporting issues.
- Objective 3: Evaluate public and stakeholder opinions on the pilot installation of LED streetlamps at selected locations.
- Objective 4: Analyze the economic costs and benefits of replacing the existing streetlamps in the historic district with LEDs.

3.1 Objective 1: Develop Inventory Database

The Town of Nantucket had a record of 199 decorative streetlamps in the downtown historic district. These streetlamps are owned by the Town of Nantucket, maintained by Ryder Electric, and supplied with power by National Grid. The Town of Nantucket had a database of the streetlamps that contains both physical and billing characteristics such as their tariff rate, type of luminaires, lamp wattage, pole number ,street location, billing status, and streetlamp condition for maintenance purposes. National Grid also maintained a record of the streetlamps with similar information for billing purposes. Each entity had its own form of record-keeping for the streetlamps, but these records are incomplete and not accessible to the other parties. The Town of Nantucket Energy Office was interested in creating one database for all the stakeholders to have access to view and modify. To develop and design a new database, the team conducted in-person interviews with stakeholders to discuss the type, structure, content, and maintenance of the database. The team consulted with the Nantucket Energy Office to identify key contacts and refine the topics for discussion prior to the interviews. Some of the main stakeholders interviewed were Ryder Electric, DPW, and National Grid to gather information pertaining to the inventory. We asked the stakeholders about issues they had encountered utilizing databases in

general and why it was difficult for them to convey information to different parties as seen in Appendix A.

With the knowledge obtained from the stakeholders, the team went to each individual streetlamp and logged all the appropriate data. To efficiently gather data, we utilized an iPad provided by the Energy Office and an application called FormConnect Pro. Within this software, we created an easy to navigate form to plug in data for each location as seen in Appendix B. Some of the topic areas included the physical condition of the fixture and pole, as well as the bulb type and wattage that was contained within the fixture. The application had a feature that allowed the ability to export the data into an excel format for ease of analyzing and manipulating.

After data collection was completed for each streetlamp, we organized the data into a format which was easy to navigate and update. We considered whether the format could be viewed by multiple users, automatically updated, and accessed from any device easily. The team decided to use Google Spreadsheet for the Town streetlamp inventory database after identifying the above desired characteristics within the program. Google Spreadsheet can be accessed using any web browser and every modification to the database is automatically saved and stored on the web, reducing the need to keep a master file in a physical location. All the data from the FormConnect Pro application was imported into the Google Spreadsheet (Figure 15). The Data Validation Tool was used to provide the user with a set of possible input values for each column. This feature prevents data being entered in the cell unless it is of an appropriate type to eliminate false input of values.

	A	B	C	D	E	F	G	H
1	Date Last Edited	Post Number	Status	Initial Input Date	Functional	General Location	Latitude	Longitude
2		1	Issue Has Been Reported	10/29/2014	Yes	12 Main St.	41.2837°	-70.0976°
3		2	Issue Has Been Reported	10/30/2014	No: Stays Dark	12 Washington St.	41.2836°	-70.0976°
4		3	Issue Has Been Reported	10/30/2014	No: Stays Dark	Corner Washington St. and Salem St.	41.2833°	-70.0975°
5		4	Issue Has Been Reported	10/30/2014	No: Stays Dark	Corner Washington St. and Salem St.	41.2832°	-70.0975°
6		5	Issue Has Been Reported	10/30/2014	No: Stays Lit	Corner Washington St. and Salem St.	41.2832°	-70.0976°
7		6	No Issues At Present	10/30/2014	Yes	Washington St.	41.2835°	-70.0977°
8		7	No Issues At Present	10/30/2014	Yes	Corner Salem St. and Candle St.	41.2833°	-70.0972°
9		8	No Issues At Present	10/29/2014	Yes	16 Main St.	41.2836°	-70.0975°
10		9	No Issues At Present	10/30/2014	Yes	Center of Lower Main St.	41.2836°	-70.0979°
11		10	No Issues At Present	10/29/2014	Yes	Corner of Main St. and Union St.	41.2835°	-70.0980°
12		11	No Issues At Present	10/29/2014	Yes	30 Main St.	41.2835°	-70.0981°
13		12	No Issues At Present	10/29/2014	Yes	26 Main St.	41.2834°	-70.0984°
14		13	No Issues At Present	10/29/2014	Yes	34 Main St.	41.2834°	-70.0985°
15		14	Issue Has Been Reported	10/30/2014	Yes	38 Main St.	41.2834°	-70.0986°
16		15	No Issues At Present	10/29/2014	Yes	44 Main St.	41.2833°	-70.0988°
17		16	Issue Has Been Reported	10/30/2014	Yes	54 Main St.	41.2832°	-70.0991°
18		17	No Issues At Present	10/29/2014	Yes	56 Main St.	41.2831°	-70.0993°
19		18	Issue Has Been Reported	10/29/2014	Yes	62 Main St.	41.2830°	-70.0995°
20		19	No Issues At Present	10/29/2014	Yes	Corner Fair St. and Main St.	41.2829°	-70.0998°
21		20	No Issues At Present	10/29/2014	Yes	72 Main St.	41.2828°	-70.1002°
22		21	No Issues At Present	10/29/2014	Yes	76 Main St.	41.2827°	-70.1006°
23		22	No Issues At Present	10/29/2014	Yes	82 Main St.	41.2824°	-70.1012°
24		23	Issue Has Been Reported	10/29/2014	Yes	90 Main St.	41.2819°	-70.1019°
25		24	No Issues At Present	8/29/2014	Yes	94 Main St.	41.2818°	-70.1020°
26		25	No Issues At Present	10/29/2014	Yes	96 Main St.	41.2817°	-70.1022°
27		26	No Issues At Present	10/29/2014	Yes	98 Main St.	41.2814°	-70.1027°
28		27	No Issues At Present	10/29/2014	Yes	Corner of Main St. and Milk St.	41.2811°	-70.1032°
29		28	Issue Has Been Reported	10/29/2014	Yes	105 Main St.	41.2813°	-70.1030°
30		29	Issue Has Been Reported	10/29/2014	No: Stays Dark	99 Main St.	41.2815°	-70.1027°
31		30	Issue Has Been Reported	10/29/2014	Yes	91 Main St.	41.2819°	-70.1020°
32		31	Issue Has Been Reported	10/29/2014	Yes	89 Main St.	41.2820°	-70.1018°
33		32	No Issues At Present	10/29/2014	Yes	85 Main St.	41.2822°	-70.1016°
34		33	No Issues At Present	10/29/2014	Yes	83 Main St.	41.2823°	-70.1015°
35		34	No Issues At Present	10/29/2014	Yes	Corner of Walnut Ln. and Main St.	41.2825°	-70.1012°
36		35	No Issues At Present	10/29/2014	Yes	73 Main St.	41.2878°	-70.1005°

Figure 15 Portion of Streetlamp Inventory

Another benefit of using this system was the ability to give multiple individuals simultaneous access to view and modify the database from various device browsers. This is useful when it is necessary to share certain data about the streetlamps with an electrician at Ryder Electric or a representative at National Grid with the ability to modify certain fields instantly through a smartphone. In addition to the general information on the streetlamps, a separate sheet was created on the database spreadsheet for a maintenance record that is linked to an online form. This online form was created to capture the repairs done on each of the streetlamps for a record of the maintenance history. This would provide the individual performing maintenance and the stakeholders the ability to see a pattern of the troublesome streetlamps and identify problematic streetlamps which constantly need repair.

3.2 Objective 2: Develop Interactive Map

The team created an interactive map as a centralized place for public access in order to view the streetlamps' current statuses and report any issue if it has not been brought to attention prior. The interactive map would allow communication between the public and the officials more efficiently. We considered two options for the interactive map, ArcGIS and Google My Maps. ArcGIS software was embedded on the portable GPS Mobile Mapper, which was able to gather GPS coordinates of the streetlamps through satellite signals. ArcGIS software could have

multiple layers on top of the Nantucket landscape map, giving the administrator the capability to plot different data sets using GPS coordinates and provide additional information for each plotted point on a particular layer. The GPS Mobile Mapper needed at least four to five satellite signals to provide accurate coordinates but the device only detected one signal at most when the team tried to utilize it. We looked for another alternative because accuracy was vital as there was tiny variation in the distances between each streetlamp. Our sponsor suggested Google My Maps for the interactive map since it allowed the administrator to implement the data sets onto the map of Nantucket and selected information, such as numbers, text, and pictures, regarding the streetlamps could be included with each plotted point. My Maps could easily be accessed online and the administrator could provide editing permission for different individuals or viewing access only for the public. We decided to use this software to create the interactive map because of the features above. A layer for the Nantucket Decorative Streetlamps was created and the team manually plotted each of the streetlamps onto the map according to their location in Nantucket, as shown in Figure 16. For easy access, the map was placed on the Town webpage that was dedicated to decorative streetlamps.

Figure 16 Selection of Decorative Streetlamps on Google My Maps

On the interactive map, a reporting form was provided for the public to report issues regarding the streetlamps. To create the decorative streetlamp reporting form, we referenced examples from the City of Seattle and National Grid to see what information the forms contained. The team also asked the DPW and National Grid for their opinions on what important information they needed in a reporting form in order to repair the problematic streetlamp.

3.3 Objective 3: Evaluate Public and Stakeholder Opinions

The third objective of this project was to evaluate public and stakeholder opinions regarding the installation of the pilot retrofits. Accordingly, we conducted interviews with various stakeholders including town officials, local business owners, and the LED companies involved; we also conducted surveys of the public through three techniques.

3.3.1 Interviews

In collaboration with Nantucket Energy Office's Lauren Sinatra and Larry Kester from the Department of Public Works, the team established possible interview candidates and potential questions. We identified an original group of stakeholders as the basis of the expanded list of individuals who we interviewed. For organizational purposes we grouped all the interview candidates into Town Officials (Section 3.3.1.1), Town Organizations (Section 3.3.1.2), Business Owners (Section 3.3.1.3), Local Professionals (Section 3.3.1.4), Other Stakeholders (Section 3.3.1.5) or Email Interviews (Section 3.3.1.6) as displayed in Table 5.

Town Officials	Town Organizations	Business Owners	Local Professionals	Company Stakeholders
Elizabeth Gibson (Town Manager) Tobias Glidden (Selectman) Larry Kester (DPW) Kara Buzanoski (DPW Director) John Smith (DPW) Chief William Pittman (Nantucket Police Department) Leslie Snell (Deputy Director of Planning)	**Nantucket Town Association:** Charles Walters **ReMain Nantucket:** Melissa Philbrick Rachel Hobart **Nantucket Historic Association:** Mark Avery **Historic District Commission:** Linda Williams **Preservation Trust:** Michael May	Nantucket Toy Company Dreamland Theater Pharmacy Atheneum The Handlebar Cafe	**UMass Field Station:** Dr. Sarah Oktay (Director) **Maria Mitchell Association:** Dr. Peter Boyce (Research Associate) Dr. Michael West (Director of Astronomy) Kim Botelho (Director of Education)	**National Grid:** Joe Cardinal * Dave Fredericks Steven Holdgate Jim Whitehead * **LED Conversions:** Mac Lummis **PennGlobe:** Michelle Stonier **Amerlux:** Scott Thompson **Ryder Electric:** Phil Albertson **Lighting Specialist:** Lana Nathe* *Email Interview

Table 5 Interviewee List

3.3.1.1 Interviews with Town Officials

Before embarking on interviews with government officials on Nantucket, the team discussed the political and cultural context of energy issues on the island with Lauren Sinatra. By doing so prior to the interview, we were able gain an understanding of certain people's stances on energy issues, economic status of the Town, and LED lights in general.

As Town Manager, Elizabeth Gibson was concerned about how problems were resolved regarding the conditions of the streetlamps and the potential benefits of an LED conversion. We also interviewed members of the Board of Selectmen, such as Tobias Glidden, to gain their opinions on aesthetic appeal, public safety, and general streetlamp costs. The team questioned the Department of Public Works's (DPW) Larry Kester, Director Kara Buzanoski, and Operations Manager John Smith regarding their expectations for the installed LED pilot lights

including inventory aspects that were previously discussed, the current streetlamps, and the processes moving forward for maintaining the streetlamps. When questioning Mr. Smith, the team inquired about the maintenance details and history of the streetlamps. We also spoke to Chief William Pittman of the Nantucket Police Department about the importance of the lighting in assisting the police in their work. In addition, Deputy Director of Planning Leslie Snell was interviewed due to her previous experience as the Town Lighting Inspector and her knowledge of the Town lighting bylaws.

3.3.1.2 Interviews with Town Organizations

We interviewed Charles Walters from the Nantucket Town Association (NTA), which is a nonprofit association that represents the homeowners in the downtown area on the subject of the possible conversion to LEDs and the historic district as a community. The team also held an interview with Rachel Hobart and Melissa Philbrick of ReMain Nantucket, which is a prominent philanthropic organization on the island. We discussed topics such as the positive and negative impacts of the LED conversion on the preservation and conservation of the Town. Since one of the nine pilot lights was installed outside the entrance to the Whaling Museum, we emailed interview questions and the online survey to Mark Avery at the Nantucket Historic Association (NHA). Individuals from the Historic District Commission (HDC), the commission involved in the conservation of the island's historic appeal, were interviewed about topics relating to the preservation of the historic district. We also emailed a representative from the Preservation Trust, Michael May, to ask his opinion from an historic preservationist's point of view and the acceptance of the possible LED retrofit conversion.

3.3.1.3 Interviews with Business Owners

A key group of stakeholders were the business owners and town employees in the downtown area. The team conducted these interviews within the business or through email. The team questioned whoever was present at the location at the time of the visit and then we sent follow up emails at a later time. We also encouraged the business owners that we emailed to reach out to other employees to gain their insight as well. We contacted various businesses such as The Handlebar Café, The Nantucket Toy Company, Dreamland Theater, the Pharmacy, and the Atheneum. Their personal and professional views on the LED streetlamps were not only

important but also the comments made by their customers about the lights that the business owners shared in the interviews. Questions included topics about whether or not the subject noticed the LED pilot lights and their general opinions. The questions explored the specific reasons why people do or do not prefer the LED lights over the old streetlamps and the potential impact on the Town and the downtown business.

3.3.1.4 Interviews with Local Professionals

The team also contacted and interviewed various professionals on the island. The list included Dr. Sarah Oktay, who is a chemical oceanographer associated with the UMASS field station and the Conservation Commission, Dr. Peter Boyce, an astronomer who wrote the bylaws regarding the lighting on the island, and Dr. Michael West, an astronomer who is Director of Astronomy at the Maria Mitchell Association (MMA). The questioning for this group of scientists pertained to the issue of preserving the dark skies on the island, the lighting ordinance in place at the time, and risks revolving around light pollution. A contact at the Maria Mitchell Association (MMA), Director of Education Kim Botelho, was also contacted for an interview. The MMA is an association involved in the preserving of the night sky and the promotion of astronomy in the community. We asked these individuals their opinions about the LED lights' possible impacts on the night sky and the island's environment as a whole.

3.3.1.5 Interviews with Other Stakeholders

The team gathered the opinions of representatives of different companies on and off the island through various interviews. We contacted National Grid's Dave Fredericks, a retired employee, and Steven Holdgate, who is currently employed as the Nantucket local branch manager. We discussed the company's current protocol and processes pertaining to the decorative streetlamps and their energy conservation and monetary motives for the LED conversion.

We spoke with representatives from the three LED retrofit pilot companies, Penn Globe, LED Conversions and Amerlux, to determine their opinions about how well the LED retrofits would fit within the Town's atmosphere and also to solicit their feedback about prior installations conducted in other towns. We inquired about aspects of the retrofit light kits, such as installation time, warranties, and other components since each company provided different

types of retrofit kits. The team spoke with LED Conversion's Mac Lummis while his company installed their LED retrofit into the two pilot locations. Both the representatives from PennGlobe, Michelle Stonier and Marcia LaFemina, and Amerlux, Scott Thompson, were contacted through email with the interview questions pertaining to each retrofit kit. After the initial emailed questions, the team and sponsor held conference calls with individuals of each company inquiring further into the monetary details of the products.

We interviewed Ryder Electric, the company that maintains the streetlamps in the downtown area. The topics discussed with Ryder were based on their past experience with LED light installations and their opinion of the potential for a complete streetlamp overhaul. We held this line of questioning while the Ryder Electric crew was installing the Amerlux retrofit kit. Phil Albertson, the representative identified from the company, answered our questions at the site of the installations and in a follow up email.

3.3.1.6 Email Interviews

We also administered email interviews for a crucial group of people who were not located on the island or we could not meet in person. Each interviewee was initially contacted to ask about their participation in our research and questioning. A short list of questions was created by the team for each individual and each was approved before being sent. Joe Cardinal, an employee of National Grid received questions pertaining to the current protocols of the company and the effect of the LED installation on the tariff rates. Our sponsor suggested contacting Lana Nathe, a lighting specialist and third party electrician who worked with Amerlux, to receive her expectations for the conversions and installations, and her opinion on LED technology in general. The team and sponsors were also in constant contact with Jim Whitehead, Lead Sales Representative at National Grid, discussing the incentives for the retrofits needed for the economic analysis.

3.3.2 Public Surveys

The team gauged the attitudes of the public through three different variations of surveys. The site-specific survey (Section 3.3.2.1) was conducted after dark in the vicinity of the LED installations in the downtown historic district. The supplemental online survey (Section 3.3.2.2) administered through online forms did not require surveying downtown during the hours of darkness. The third was QR code surveys (Section 3.3.2.3) relating to each LED retrofit pilot. Found in Appendix C, all the surveys included questions about people's observations of the HPS lights and the pilot LED lights. Each survey was entirely anonymous and no identifying information was collected.

3.3.2.1 Site-Specific Survey

At least two team members facilitated the surveys at night near the designated nine pilot sites as illustrated in Figure 17. It was necessary to conduct them in the darker hours so that the consenting adult pedestrians that were surveyed could actually see the lights that the survey was referring to.

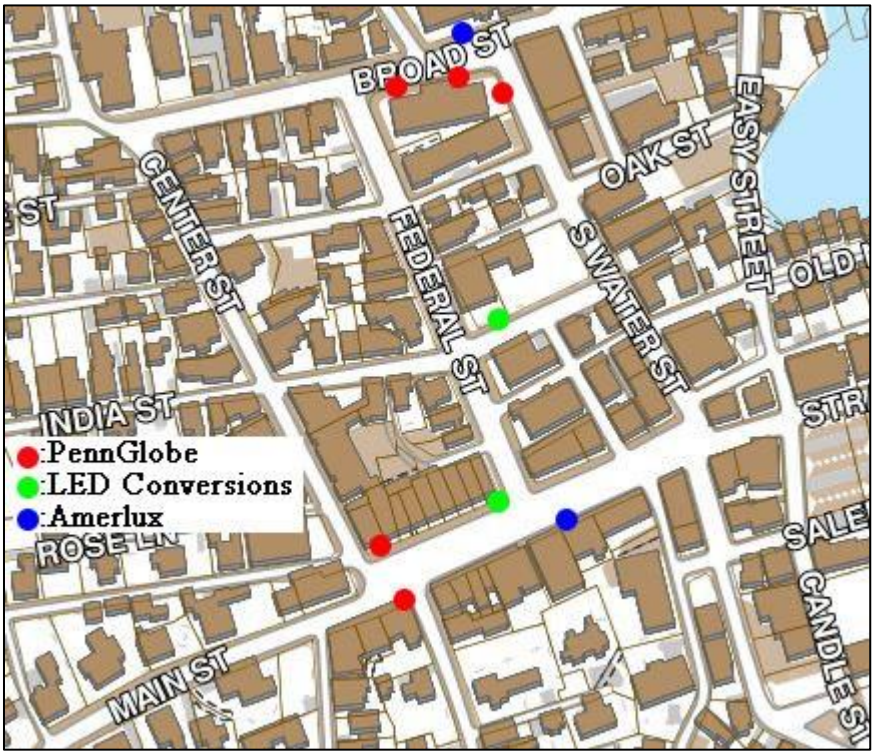


Figure 17 LED Pilot Site Locations

Development and Pretesting

The team created a pilot survey that contained both open-ended questions and closed-ended questions used for pretesting. We reviewed prior surveys and consulted with the sponsors and advisors to determine topics and questions for the preliminary surveys. A pilot test of 18 respondents was used to evaluate and refine the initial survey instrument and the survey delivery protocols.

Refining and Delivery

The pilot testing was used to revise the draft survey and refine the delivery and data collection protocols. We analyzed the relevant information collected in the pretesting including most successful methods and times to survey, and also the questions and answers supplied. Many responses from pedestrians included comments on the excessive length of the survey, the difficulty of answering open-ended questions in cold weather, and the areas of unclear wording. Although the team did not want to prime people's responses, definite answers were desired to code and analyze after the process of surveying was complete. The survey provided the option of "Unsure" if the participant did not agree with the other choices. We opened the in-person street surveys with demographic questions, followed by general streetlamp questions. Then the participant was informed that LED lights were installed in the vicinity and asked if they had noticed any of the LED lights. Specific questions pertaining to LEDs and the conversion concluded the survey. The team either administered the survey verbally or handed the participant a paper form to complete. For especially cold nights or elderly pedestrians, the survey was given verbally. For large groups of participants, the paper forms of the survey were distributed to enable each member of the group to complete a survey simultaneously and maximize the sample size.

Key times for conducting the in-person on the street surveys were on weekends and during Christmas Stroll, when more people were in the downtown area, maximizing the number of people exposed to the streetlamps. However, we desired the widest variety of survey participants that was possible in this situation, so surveys were also conducted at calmer times, for example a Wednesday night. We continued surveying throughout the project, collecting as many responses as possible to analyze.

3.3.2.2 Online Survey

Another technique of gaining the public's attitude was to circulate a supplementary survey to people online. The team and sponsors emailed this survey to many organizations and contacts. In addition, the survey was available online on the Town's website for the public to access. This survey was pretested and developed in the same way that the site specific survey was created. These surveys contained similar questions; the online version was greatly influenced by questions in the initial in-person survey that were eliminated after pretesting to condense the length. A large difference between the two was that the online survey did not ask questions directly related to a specific pilot site because participants did not completed the survey at a specific location. Questions in this survey not only consisted of the people's opinion of the lights downtown, but also general questions of people's knowledge of LEDs as a whole and the conversion process.

3.3.2.3 QR Code Survey

The QR code surveys for the specific pilot locations were accessed through a QR code placed on the streetlamp as shown in Figure 18 in order for a pedestrian to self-administer the questionnaire. It was a way to gain more responses from participants at sites without needing our presence. The team created nine different QR codes so the results for each pilot site would be recorded separately while still presenting the same questionnaire. The survey itself contained three questions regarding the LED light where the QR code was located and concluded with demographic questions. Once scanned, the QR code prompted the person with the survey and informed them that it is anonymous therefore no emails or phone numbers were recorded.

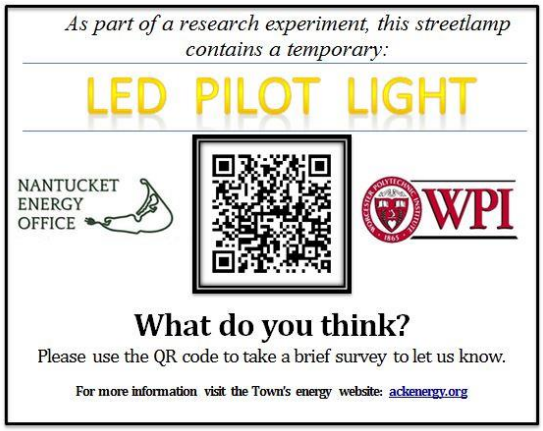


Figure 18 Pilot Site QR Code Tag

3.4 Objective 4: Analysis of LED Costs and Benefits

The team conducted an economic analysis calculating the costs and savings associated with the replacement of all the decorative streetlamp fixtures in the historic core districts with LEDs. The analysis required a range of information on the streetlamps that was obtained from the involved stakeholders. The team received information on maintenance costs for the HPS bulbs through invoices from Ryder Electric, who performed electrical maintenance on the streetlamps. We obtained the initial purchase and installation costs, and long-term operating and maintenance costs of the LED retrofits through communication with the three LED retrofit companies. The team communicated with National Grid on the impacts of the different tariff rate, S-5 rate, for the LED conversion and the possibly negotiable financial incentives for a full conversion. The cost analysis summarized the benefits of converting all the town-owned decorative streetlamps to LEDs, specifically focusing on maintenance cost reductions and decreased energy usage costs.

The team assembled an economic analysis of the possible reduced costs specifically from National Grid in regards to the tariff rates that would change from S-3 to S-5 with the installation of LEDs. The S-5 tariff rate is for customer-owned streetlamps that are being converted to LED retrofits with National Grid no longer being responsible for maintaining the light bulbs or photocells. In order to estimate these cost savings obtained from the reduced tariff rate, the team determined the energy savings using an S-5 summary for LED retrofits included in Appendix D. Using an Excel document created according to the steps in the S-5 summary, the team calculated the estimated National Grid tariff rate the Town would have to pay according to the S-5. The information required for the calculation was obtained from the streetlamp database and the National Grid streetlamp energy bills for the 2014 fiscal year. The database supplied the current HPS lamp wattage and replaced LED wattage, which was under 50 watts for each of the pilot retrofit kits indicating the need to only calculate for one scenario of an LED conversion. The energy bills for the months of the 2014 fiscal year were used by the team to determine the S-3B electricity tariff cost paid by the Town for each month as the rate varied based on estimated hour usage. After determining the current tariff rate, the Excel document created by the team calculated the total existing annual cost under an S-3B tariff rate and the total LED annual cost under an S-5 tariff rate. We then determined the estimated total annual energy cost savings by

subtracting the estimated S-5 cost from the S-3B cost for a general cost difference from the change in National Grid tariff rate.

In order to compare the companies, we used the information collected from each of the three LED retrofit companies to assess the overall cost of the retrofits and installation costs. The information was compiled into tables including the LED wattage, cost per retrofit, installation cost, and warranty for the each LED company. The team calculated the expected total cost of the LED retrofits for each company and the total installation cost. In addition, National Grid was contacted to determine the amount of the incentive that would be provided for the LED conversion. It was then subtracted from the cost per fixture to allow the calculation of the reduced total cost of the retrofits. The current cost of the streetlamps with HPS bulbs that require maintenance was used to determine the cost savings associated with the LED retrofits and the estimated payback periods per company. We organized the economic analysis data into a visual comparison of the three LED retrofit companies and the overall cost savings for the LEDs, including the projected cost and payback periods to share the results. Using this information from the various tools, the Town of Nantucket could decide if LED retrofits are a beneficial and feasible option.

Chapter 4: Findings and Analysis

The following chapter presents the results of the research we conducted for the Town of Nantucket Energy Office. We discuss the completed inventory database and interactive map and the results of the surveys conducted on the conditions of the streetlamps and the installed pilot LEDs. We also discuss the insights from the numerous interviews the team conducted and the outcome of the economic analysis. With this plethora of information the team was able to present a recommendation to the Town concluding the project. Based on the information within the chapter, we conclude that the historic streetlamps present an ongoing maintenance challenge for the Town and there are desirable benefits of LEDs such as reduced maintenance, reduced cost, and reduced energy use. We recommend how the Town might implement an improved maintenance protocol and an LED streetlamp conversion in the future.

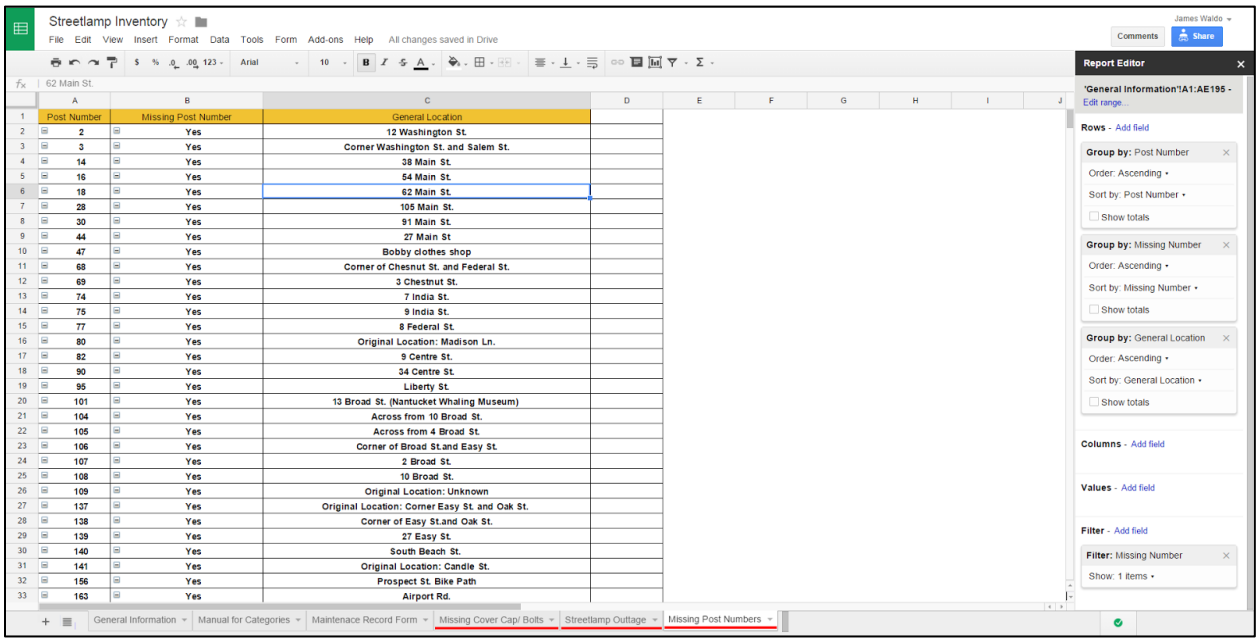
4.1 Inventory and Maintenance

From the completion of our inventory we determined there were 194 lamp locations in existence with six missing streetlamp fixtures. In addition to these missing fixtures, there were 23 streetlamps with functioning issues; 19 that remained dark, two that were always on, and two streetlamps with cycling issues where the light constantly turned on and off. There were multiple lamps in questionable shape including missing components and unbalanced structures.

As previously stated in Section 3.1 of our methods, we created a Google Spreadsheet for the Town of Nantucket to utilize for maintenance and inventory purposes. Any town official given access to this new database will be able to update the inventory easily on any device browser. To make this database easier to modify for the average person, we utilized the Data Validation Tool within Google Spreadsheet which inserted dropdown menus for all categories to ensure no data was falsely inputted.

With the many categories in this database and the vast amounts of information, we realized it would take a great amount of time to locate information effectively. To solve this we created separate Pivot Tables which filter through the entire database and display only certain subsets of information. For example in Figure 19, the pivot table only displays the streetlamps which are missing their identification numbers, along with their location and any other fields of

interest. This is done to make it easier for problem streetlamps to be identified and fixed without having to go through and manually find the issues.



Post Number	Missing Post Number	General Location
2	Yes	12 Washington St.
3	Yes	Corner Washington St. and Salem St.
14	Yes	38 Main St.
16	Yes	54 Main St.
18	Yes	62 Main St.
28	Yes	105 Main St.
30	Yes	91 Main St.
44	Yes	27 Main St
47	Yes	Bobby clothes shop
68	Yes	Corner of Chesnut St. and Federal St.
69	Yes	3 Chestnut St.
74	Yes	7 India St.
75	Yes	9 India St.
77	Yes	8 Federal St.
80	Yes	Original Location: Madison Ln.
82	Yes	9 Centre St.
90	Yes	34 Centre St.
95	Yes	Liberty St.
101	Yes	13 Broad St. (Nantucket Whaling Museum)
104	Yes	Across from 10 Broad St.
105	Yes	Across from 4 Broad St.
106	Yes	Corner of Broad St.and Easy St.
107	Yes	2 Broad St.
108	Yes	10 Broad St.
109	Yes	Original Location: Unknown
137	Yes	Original Location: Corner Easy St. and Oak St.
138	Yes	Corner of Easy St.and Oak St.
139	Yes	27 Easy St.
140	Yes	South Beach St.
141	Yes	Original Location: Candle St.
156	Yes	Prospect St. Bike Path
163	Yes	Airport Rd.

Figure 19 Pivot Table of Missing Streetlamp Number

The database will be stored on the web in order to be maintained by the DPW and the Nantucket Energy Office. For stakeholders, such as National Grid and Ryder Electric, who would like to view the database, the document can be published to a web URL and emailed to any user to be viewed from any web browser without the need of a login account. The information presented on that URL is updated constantly to keep the data accurate. If for any reason the document needs to be taken off that web URL, there is an option to un-publish the database.

We also created a maintenance form on Google Forms. This form will be utilized by the administrator of the database, who will record repair information received from National Grid, Ryder Electric, DPW, and other companies after they perform maintenance on the streetlamps. This information will then be stored on the inventory Google Spreadsheet for an accurate updated maintenance record. This maintenance record would be able to identify specific streetlamps which are constantly being worked on, indicating problems that have gone undetected and need further investigation. The vital information that this form would capture

would be the particular type of maintenance performed on the streetlamp, who requested the work, potential invoice number, and other categories as seen in Appendix E. This form would be included in the issue reporting process and the updating of the database which is discussed further in Section 4.2 below with the incorporation of the interactive map.

4.2 Interactive Map and the Public Reporting Process

The Town officially took ownership of the decorative streetlamps in 2006, shifting the responsibility to the public to inform Town officials rather than National Grid when there are problems with the streetlamps. Prior to our project, the Town did not have a systematic method for the public to report issues regarding the decorative streetlamps. Based on interviews with the DPW and National Grid, we learned that they often received complaints about the streetlamps through phone calls or email. When an issue was reported, there was no consistency in the chain of communication afterwards. To organize the communication, the team developed an interactive map as a reliable method for the public to communicate issues to the appropriate officials, such as DPW and National Grid.

The team manually plotted all the decorative streetlamps throughout Nantucket on Google My Maps. The data table of My Maps records information for all the plotted streetlamps by categories, such as name, location, bulb type, wattage, current status, and more. With many data inputs, My Maps allows the administrator to show certain categories for the public to access while still having vital data for the administrator to utilize. In addition, the plotted icon could change in appearance based on the input in a particular category field. Any streetlamp sharing the same input would have the same icon, allowing the viewers to visualize a certain type of data, such as the example in Figure 20.

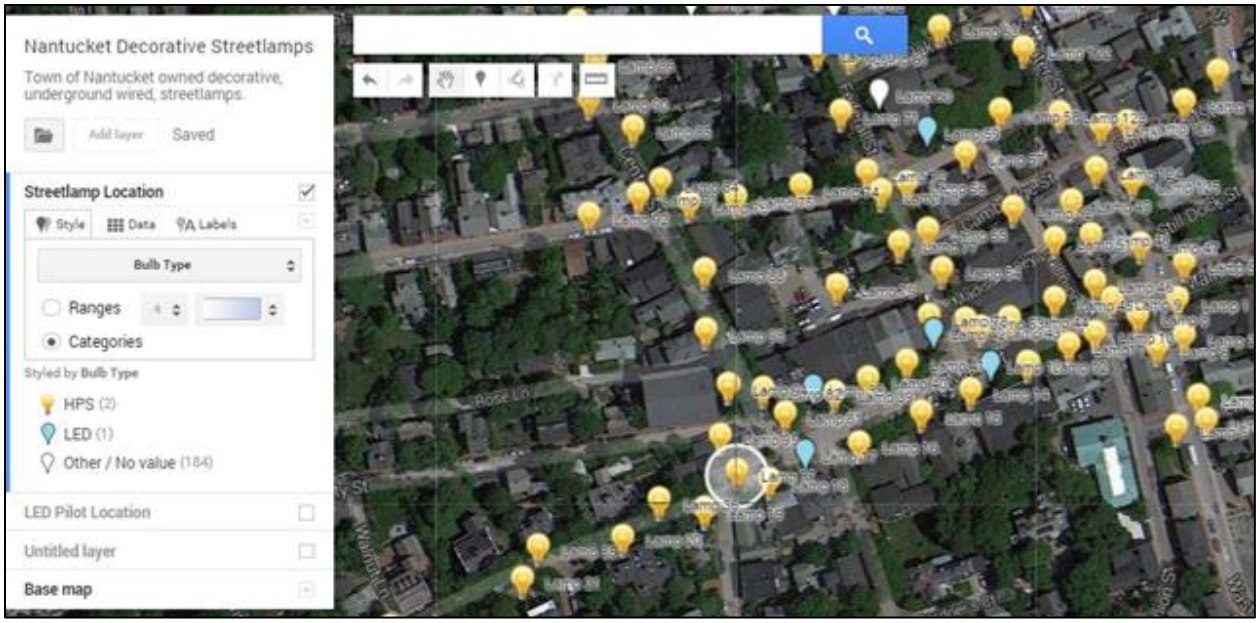


Figure 20 Visual of Streetlamps with LED (Blue) and HPS (Yellow) Bulb Type

When a map icon is selected, the public can see a box that displays a daytime picture of the lamp, the lamp post number, location, current status, and presents the user with an option to report an issue (Figure 21). The picture serves as a visual aid to ensure the correct streetlamp is identified. The post number is vital to ensure a timely and efficient response by maintenance crews. The "Current Status" field lets the public know the streetlamp's repair status. "No Issue Present" means the streetlamp has no issue and is functioning properly, "Issue Has Been Reported" means an individual has notified the officials that the streetlamp has at least one issue,"Issue is Being Addressed" means the streetlamp is in the process of being repaired, and "Remove From Inventory" means that streetlamp was removed with no intent for reinstallation. The icons are colored yellow, red, green, or black respectively (Figure 22). The Town streetlamp administrator (TSA) is responsible for regularly updating the current status in the database and on My Maps, which automatically changes the icon color accordingly. The updating process is explained below.

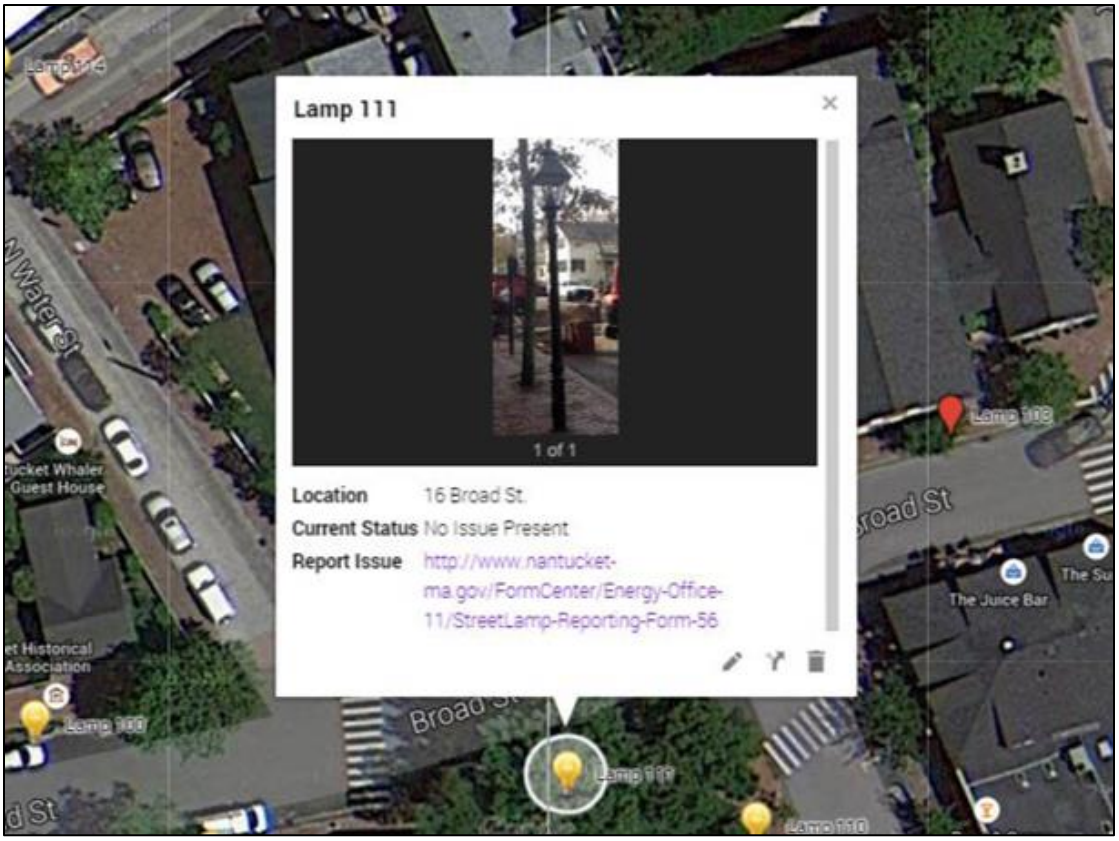


Figure 21 Data Being Displayed When a Light is Selected

Figure 22 Different Icons Used to Represent the "Current Status"

After consulting with National Grid, Ryder Electric, and representatives from DPW, we decided to include a record of the date of the last maintenance for each individual streetlamp, the "Last Inspection" category. The "Report Issue" field would supply a link to a reporting form the team created for the public to notify DPW, the Energy Office, National Grid, and TSA on issues regarding the streetlamps. The reporting form, shown in Figure 23, would ask the individual reporting the issue to provide the post number and general location to notify the officials of the problematic streetlamp. The public can also utilize the interactive map to enter information about the troubled streetlamp's post number and general location. The form allows the user to choose multiple possible issues that best fit their concerns about the streetlamp such as light out, cycling issue, damage, and others.

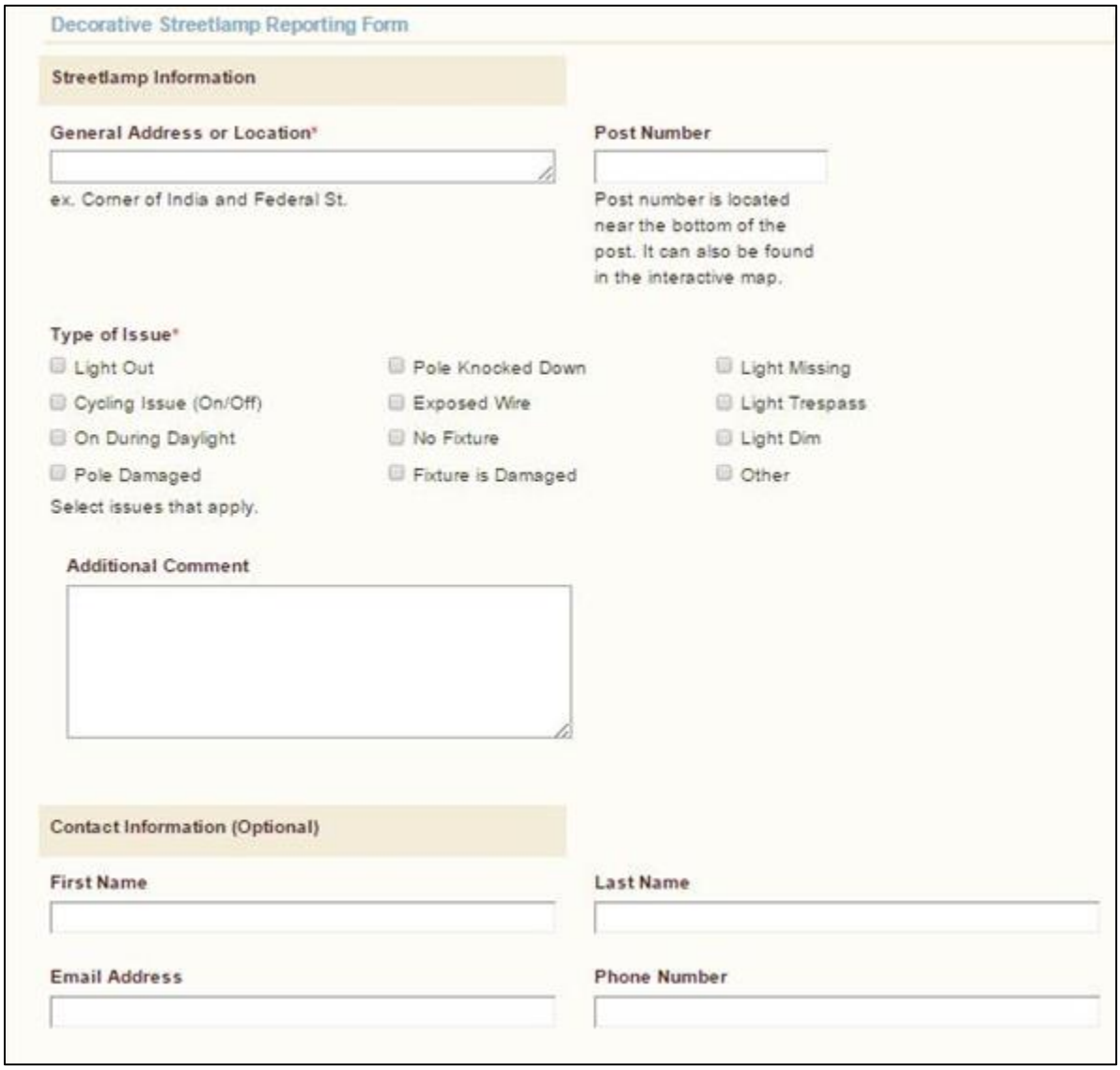


Figure 23 Decorative Streetlamp Reporting Form

The form has a feature that allows emails to only be sent to individuals responsible for certain issues based on the choices reported by the public. A field for additional comments is included on the form in case the individual would like to elaborate further about the issues or could not find a description that fit the problem. The individual also has the option to provide personal contact information in case the officials would need further clarification or additional detail about the streetlamp. The contact information is not required for those who wish to remain anonymous.

Once the individual submits the reporting form, it would be sent to the mailing list consisting of representatives responsible for the maintenance of the decorative streetlamps like DPW, the Energy Office, National Grid, and the TSA. The mailing list could be edited to reflect the current representatives responsible for the maintenance process at that time. As emphasized by John Smith, the reports should be sent to multiple individuals to avoid the information being stalled by one person, resulting in a discontinuation of communication (John Smith, personal communication, November 12, 2014).

We created two flow charts as visual aids for the maintenance representatives to follow the process of communication after a reporting form was completed, shown in Figure 24 and 25. National Grid would address the reports involved with the functionality or first emergency response for of the streetlamp and the DPW would address structural or environmental issues reported.

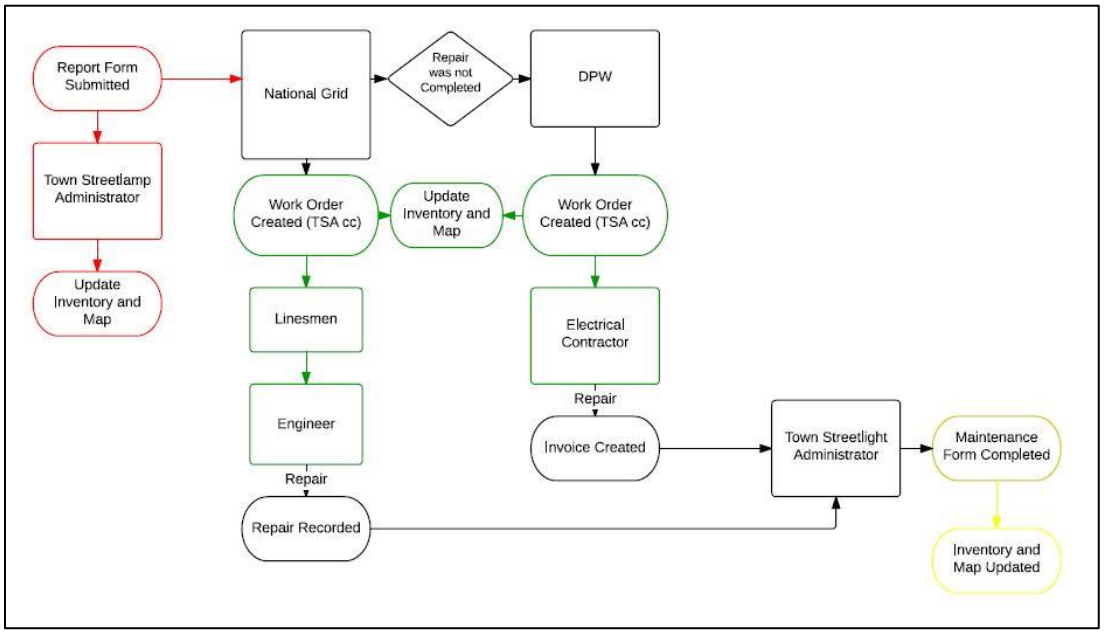


Figure 24 Chain of Communication for Functionality Issues and Emergency Response

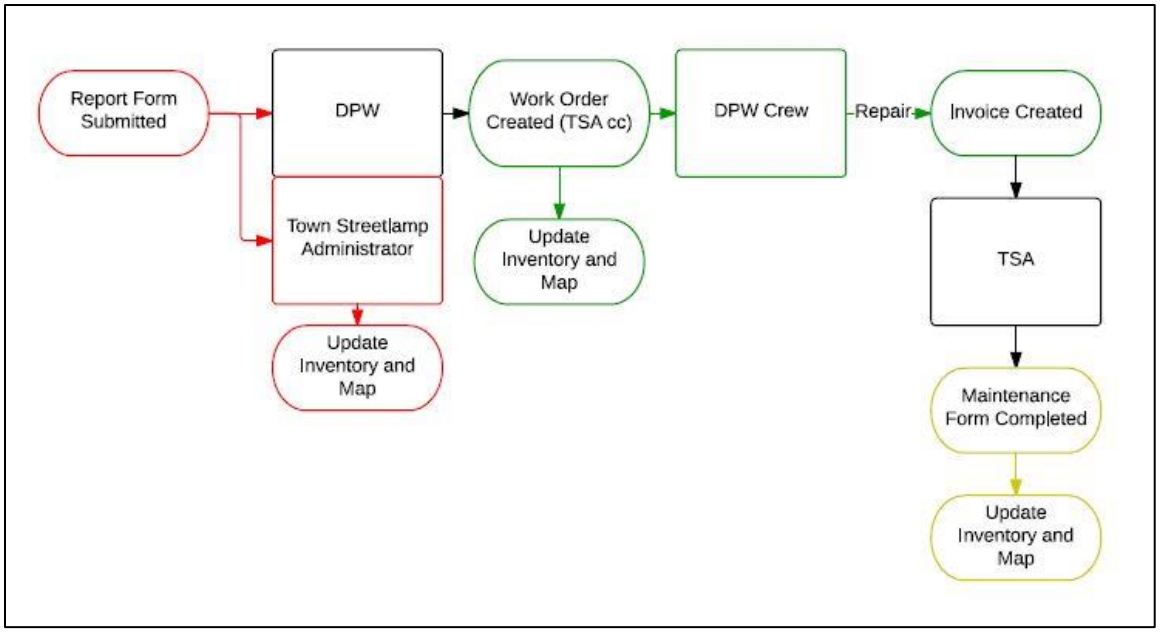


Figure 25 Chain of Communication for Structural or Environmental Issues

The TSA would receive all issues to update the inventory and interactive map status. If an issue was reported, the update would change from "No Issue Present" to "Issue Has Been Reported" and include a brief description of reported issue on My Maps. The TSA would then receive an email from National Grid or DPW when a work order was created to update the current status to "Issue is Being Addressed". Once the repair was carried out by National Grid, DPW, or Ryder Electric, an invoice or a communication would be made by the repair individuals to the TSA via email to complete the maintenance form mentioned in Section 4.1. The TSA would also update the inventory and interactive map to "No Issue Present" and record the date of repair in "Last Inspection" field in the map. The team provided a manual for the TSA to follow step by step for each scenario (Appendix F) and also a manual on how to use other features on My Maps (Appendix G).

The team created a main webpage called "Decorative Streetlamps" on the Town website to provide a centralized location for the interactive map and reporting form. There are four subpages linked to the main webpage including "Interactive Map," "History of Streetlamps," "LED Pilot Project," and "Reporting Form." The navigation for the subpages is located on the left side of the main webpage as shown in Figure 26.

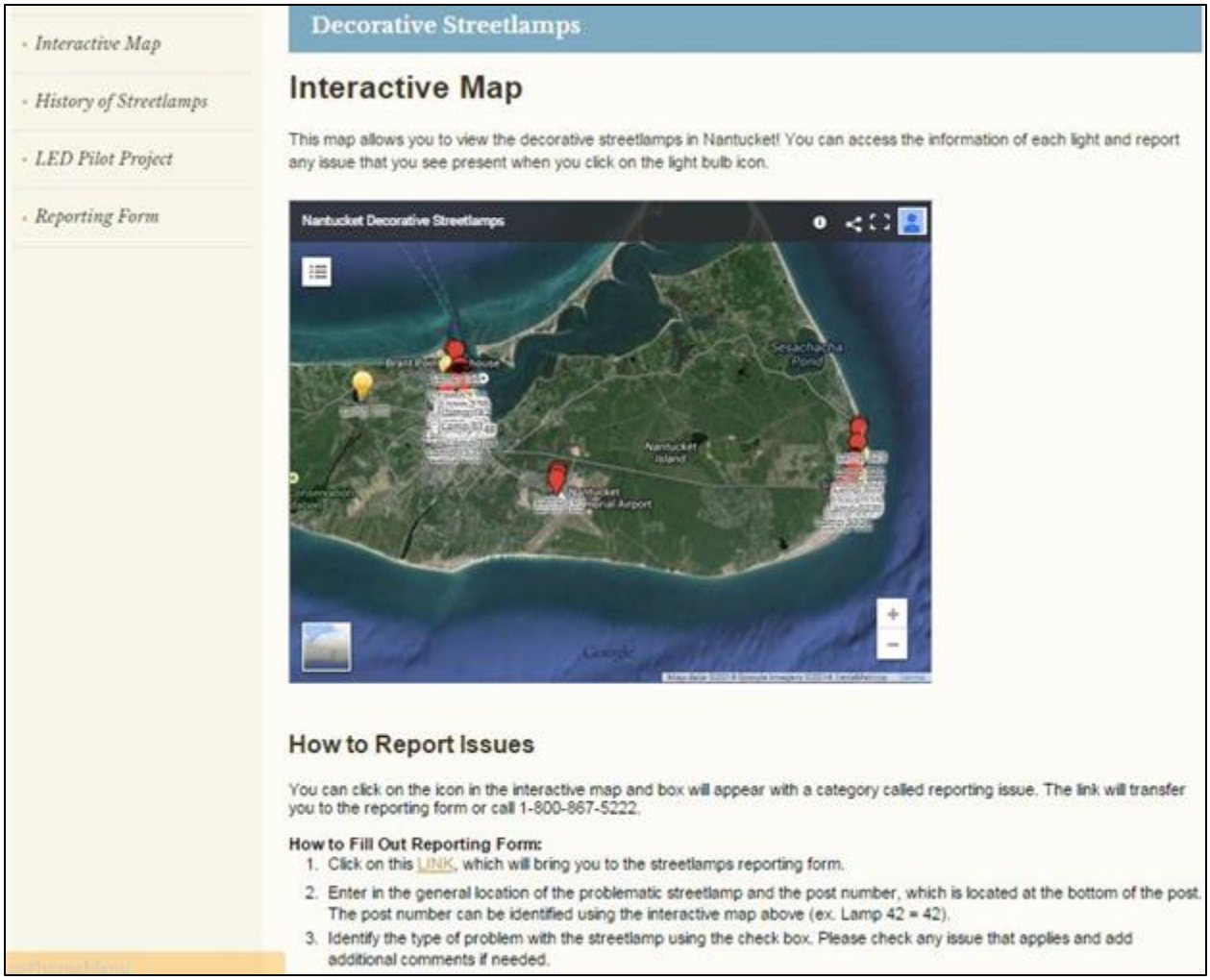


Figure 26 Decorative Streetlamp Webpage Layout

Both the "Decorative Streetlamps" and "Interactive Map" are the same webpage sharing the identical content to showcase the interactive map to the public. On the webpages, the interactive map is the first item, as shown above, with instructions to walk the public through the process of completing the reporting form. We also provided the link to the SeeClickFix application used on Nantucket to report issues if the individual is more acquainted with that application. In the SeeClickFix application, the individual can choose a category pertaining to streetlamps. Then they are prompted to enter details into the application about the specific problematic streetlamp location. Through SeeClickFix, they have the ability to take a picture of the issue to provide visualizations if they are in the field. Once submitted, this report is also sent to the appropriate officials to be reviewed and acted upon.

The “History of Streetlamps” page provides a picture of the Boulevard and Philadelphia fixtures to help the public identify the different types of decorative streetlamps. A brief history of when the Town acquired the streetlamps and a document called “Street Lighting in Nantucket” by Edourad Stackpole are provided to give the public an insight about how the features of streetlamps were decided and the reasoning behind their different appearances.

The “LED Pilot Project” webpage informed the public about the LED pilot retrofits installed in select streetlamps for a research project conducted by the Town of Nantucket Energy Office. The images of LED pilot retrofits are shown at the top of the page along with the link to the online survey the team created. A slide show of all the LED retrofits location, as seen in Figure 27, is available to help the public identify where the LED pilot sites are located and encourage them to participate in the short QR code survey. We provided facts about LEDs and case studies conducted at other cities to know more about their benefits and why cities are looking into LEDs as a lighting source for streetlamps. The “Reporting Form” page links to the same reporting form on the interactive map, providing the public many pathways to access it to report issues easily.

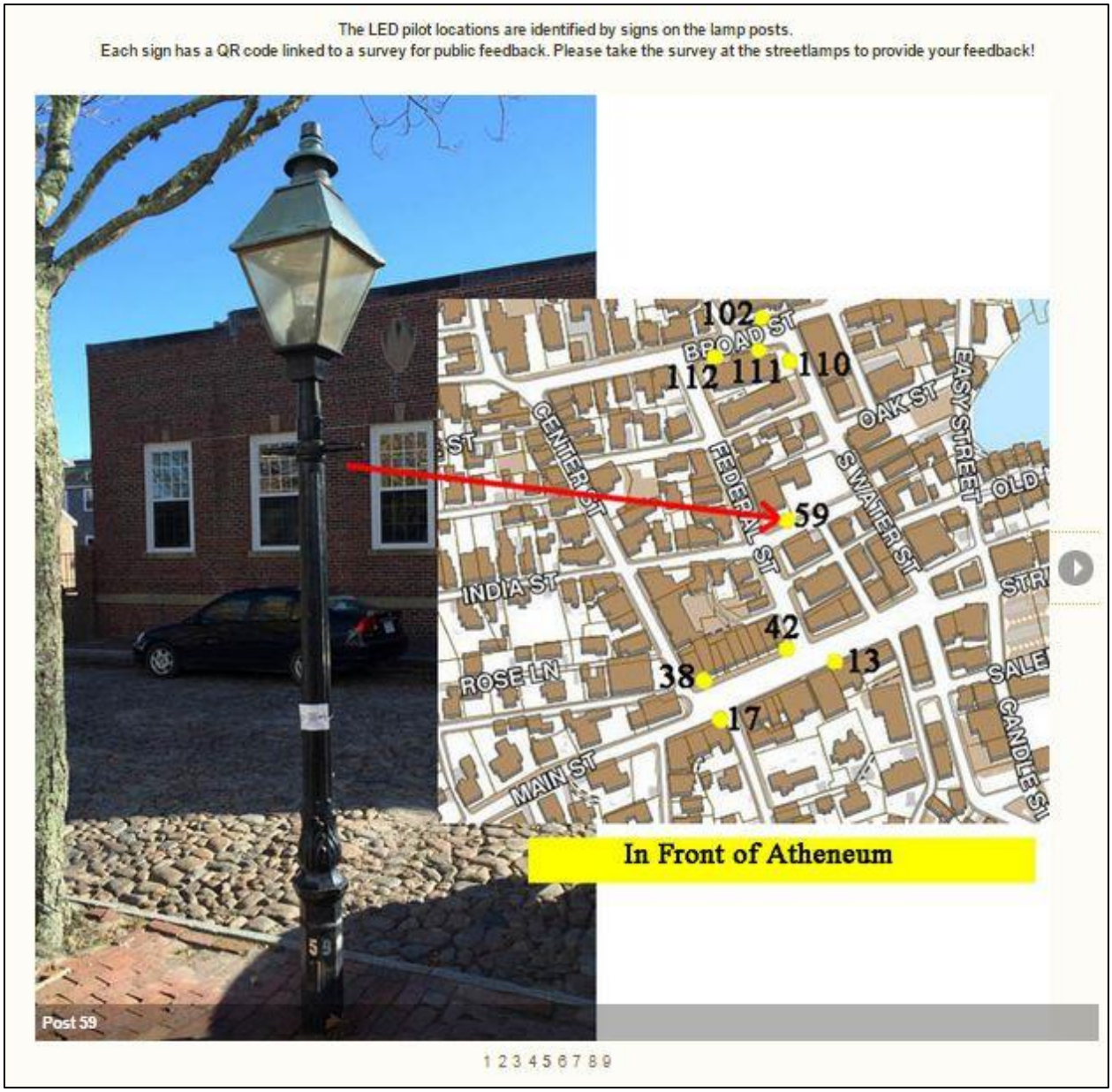


Figure 27 Slideshow of LED Pilot Sites

4.3 Stakeholder Opinion on Street Lighting and LEDs

The team interviewed about 40 individuals from various backgrounds and knowledge throughout the duration of the project. Throughout the interview process the team discussed various topics such as opinions of the current lights and new LED lights, and the procedures for inventory and maintenance of the lights. Below in Table 6, we summarized various stakeholders' comments from the interviews.

Interviewee	Credentials	Desirable Attributes	Concerns
Elizabeth Gibson	Town Manager	• Increased Safety • Decreased Energy	
Tobias Glidden	Selectman	• Increased Safety	• Public Acceptance
Rachel Hobart Melissa Philbrick	ReMain Nantucket	• Reduced Maintenance	• Salt Corrosion • Bulb Disposal
Kara Buzanoski	DPW Director	• Reduced Maintenance	• Inventory
John Smith	DPW Operations Manager	• Reduced Maintenance	• Maintenance Plan
Charles Walters	Nantucket Town Association	• Decreased Light Pollution • Reliability	
Chief William Pittman	Nantucket Police Department	• Increased Safety	
Dr. Sarah Oktay	UMass Field Station Director	• Directional Lighting	• LEDs Only in Downtown
Steven Holdgate	National Grid	• Reduced Maintenance	
Dave Fredericks	Retired National Grid	• LED Brightness	• Inventory
Dr. Michael West	Maria Mitchell Association Director of Astronomy	• Reduced Costs	• Potential Increase in Light Pollution
Linda Williams	Historic District Commission		• Historic Appropriateness

Table 6 Interviewees' Desirables and Concerns

4.3.1 Opinions of Conditions and Adequacy of Lighting

One major benefit that participants emphasized was the increased safety that they assumed would accompany the conversion to LEDs. The majority of people believed that the downtown area is not adequately lit at present. Several interviewees indicated that poor lighting was a safety risk for the Town because of the uneven sidewalks. To preserve the historic feel of

the downtown area, many of the sidewalks are brick, but they have become very uneven and broken by roots over many years. However without the adequate lighting, the sidewalks may become a dangerous liability. A large number of interviewees favored the LED lights over the HPS lights due to the increased reliability of LEDs and illuminating the difficult terrain.

Selectman Tobias Glidden and Chief of Police William Pittman were strongly in favor of the increased safety afforded by LED lights. During the interview with Mr. Glidden, we presented him with an example of the dangers of the HPS bulbs. Shown in Figure 28 below is the diffuser from the inside of one fixture where the bulb shook loose from its bearings and started to melt into the plastic diffuser due to the dangerously high temperatures.

Figure 28 HPS Bulb Melted into Fixture Diffuser

Many people who saw this damage were surprised and Mr. Glidden suggested making the public more aware of these risks and the increased safety of LEDs due to their durability and cooler physical temperatures. He also mentioned how educating the public about LED technology would help people understand why the Town was exploring the use of LEDs for streetlamps (Tobias Glidden, personal communication, November 6, 2014). The interview with Chief William Pittman addressed many aspects of the public well-being with regard to lighting. He mentioned that particular problem areas in need of better lighting were churches, hills, and sidewalks with exposed roots. He thought the core of downtown from the harbor to Center Street

should be more reliably lit. The Chief further mentioned the yellow hue of HPS bulbs made it difficult to identify people and that various problems could be avoided with better lighting (Chief William Pittman, personal communication, November 14, 2014).

4.3.2 Inventory and Maintenance

Discussion with the sponsors and members of the DPW, revealed the need for an inventory of the streetlamps. The lack of communication between Ryder Electric, National Grid and the DPW, and the absence of accurate, centralized records has created numerous maintenance issues and resulted in the Town being billed inappropriately.

We presented representatives from National Grid, Ryder Electric and the DPW with a preliminary draft of the database to determine what elements should or should not be included in the inventory. Steven Holdgate from National Grid and Phil Albertson from Ryder Electric both emphasized the importance of a post number and general location of the streetlamp (Steve Holdgate, personal communication, November 7, 2014; Phil Albertson, personal communication, November 12, 2014).

Both Steven Holdgate and Dave Fredericks mentioned that the maintenance for each lamp was once recorded in the lamp itself on a tag (Dave Fredericks, personal communication, November 4, 2014). Accordingly, we modified the maintenance section of the database to include the same categories of information previously recorded on these tags. Steven Holdgate and his crewmen also suggested that we include a reference to the last date of maintenance for each light (Steve Holdgate, personal communication, November 7, 2014).

Dave Fredericks, DPW Director Kara Buzanoski, and Town Manager Elizabeth Gibson emphasized the need for a maintenance schedule to address issues with the streetlamps (Dave Fredericks, personal communication, November 4, 14; Kara Buzanoski, personal communication, November 13, 2014; Elizabeth Gibson, personal communication, November 10, 2014). A consistent theme throughout the interviews was the failure in the past to maintain the streetlamps proactively. One concern which Dave Fredericks stated was whether any of the poles could have faulty ground wires that cause the streetlamp pole to have a voltage potential great enough to shock an individual who makes direct contact (Dave Fredericks, personal communication, November 4, 2014). Checking for such issues could be part of a regular maintenance program. DPW's Operations Manager John Smith also advocated for the future

conversion of the metal posts to fiberglass. Not only would it eliminate the possibility of becoming charged but they also require less maintenance and do not degenerate according to Smith (John Smith, personal communication, November 12, 2014).

4.3.3 Opinions on LED Aesthetics

The majority of interviewees believed that the bright white or blue colors typical of many LED lights would be inappropriate in the streetlamps on the island. However when the team showed the LED retrofit prototype in a warm color, people were pleasantly surprised and affirmed that such a light might be acceptable in the historic district. Dave Fredericks informed the team that the largest obstacle for the acceptance of an LED conversion by the public would be the color, which he knows from his experience changing the lights in the past (Dave Fredericks, personal communication, November 4, 2014). The other aspects of the lights, the reduced maintenance, reduced energy usage, and cost savings were all benefits, but due to the historic nature of the Town, the physical look of the lights may outweigh all other benefits (Lauren Sinatra, personal communication, October 29, 2014). ReMain Nantucket's Rachel Hobart and Melissa Philbrick stated that if the LED colors matched the current lighting then the conversion might be publicly accepted due to its other benefits. Philbrick was concerned about the new technologies' ability to withstand environmental corrosion on Nantucket and the bulb disposal of the existing HPS lighting (Melissa Philbrick, personal communication, November 7, 2014; Rachel Hobart, personal communication, November 7, 2014).

Another major concern raised by several interviewees was light pollution and the potential impact of LED streetlamps on the visibility of the night sky of Nantucket. Dr. Sarah Oktay, Director of the UMass Field Station, said the biggest concern in terms of light pollution was not the intensity but the directionality of the light. She suggested that if LED retrofits are directed downward and completely cut off, referring to the fixtures' ability to shield the light from projecting into the sky, they may be appropriate for the downtown area but the residential areas should remain as they are to preserve the darkness of the night sky (Dr. Sarah Oktay, personal communication, November 6, 2014). Dr. Michael West, Director of Astronomy at the Maria Mitchell Association, agreed, saying, "Properly shielded LEDs are win-win for everyone, reducing costs and light pollution at the same time" (Dr. Michael West, personal communication, December 1, 2014).

Members of the NTA were generally supportive of the LED conversion provided it would not increase the light pollution on the island. The LEDs capacity to remain on due to their reliability was a greatly condoned aspect of the conversion. Multiple members and the president, Charles Walters, told us that they had been frustrated with the lack of lighting in areas and tried to report problems with the streetlamps while living on the island (Charles Walters, personal communication, November 6, 2014).

4.4 Public Opinion on Street Lighting in Nantucket

We received a total of 126 responses (52% male, 47% female) together through the in-person survey, online survey, and QR code survey. Sixty-three percent of respondents were full-time residents of Nantucket and 37% were seasonal residents, visitors, or did not answer the question. The sample included a reasonable representation of ages although the 56-65 age range dominated with 25% of the respondents. The following sections present the results of the three separate surveys administered.

4.4.1 Site-Specific Survey

We surveyed a total of 97 people in person at night near the LED pilot streetlamp locations. The sample size of each of the nine locations varied from 10 to 12 responses and was smaller than hoped because the foot traffic and weather at the time of the year was limiting and many people, about 45% of those we asked to take a survey, refused to participate. The small sample sizes for each location narrowed the ability to draw comparisons between each location sufficiently from the responses. The in-person survey was used to ask specific questions about the nine different LED retrofits installed by the three pilot companies. These responses were based on purely the light of the LED retrofit but there were factors that affected the clear view of the retrofit light including the type of fixture either Philadelphia or Boulevard, the opacity of the glass, and the number of streetlamps in the surrounding area. The following figures compare the responses received about the different retrofits that are identified by the streetlamp post number.

Figure 9 shows how many people thought the LEDs at a particular location were appropriate for the downtown area. It appears the Amerlux 2400 K and PennGlobe 3000 K were the most popular options, although the small sample size at each location limits the validity of

these results. Overall, combining the responses from all sites, about 74% of respondents thought that LEDs were appropriate for downtown area.

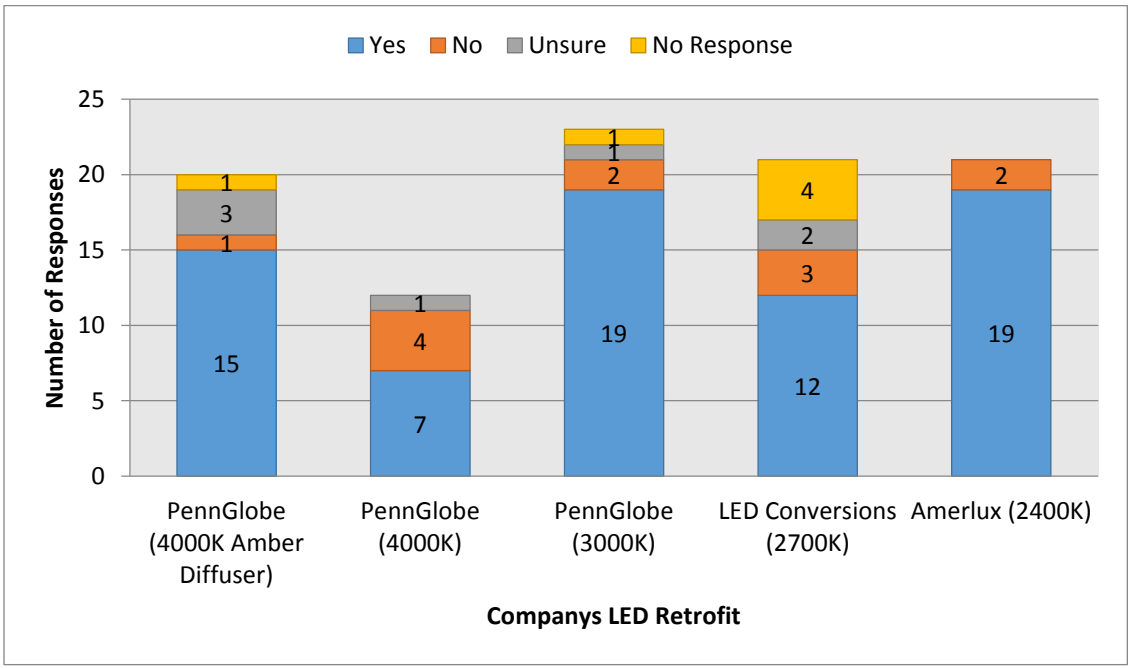


Figure 29 "Do you think this LED is appropriate for the downtown area?"

The following figures illustrate the public's feedback for questions from the survey that rate the characteristics of the LED. According to the scale, a response of one is "Strongly Dislike" and five is "Strongly Like." The ranking on the brightness of the LED lights are displayed in Figure 30, indicating that the public generally appeared to like the brightness of the LEDs with the majority of respondents answering "Like" or "Strongly Like." As a comparison, the average values of the responses for each of the companies' different install locations are graphed in Figure 31.

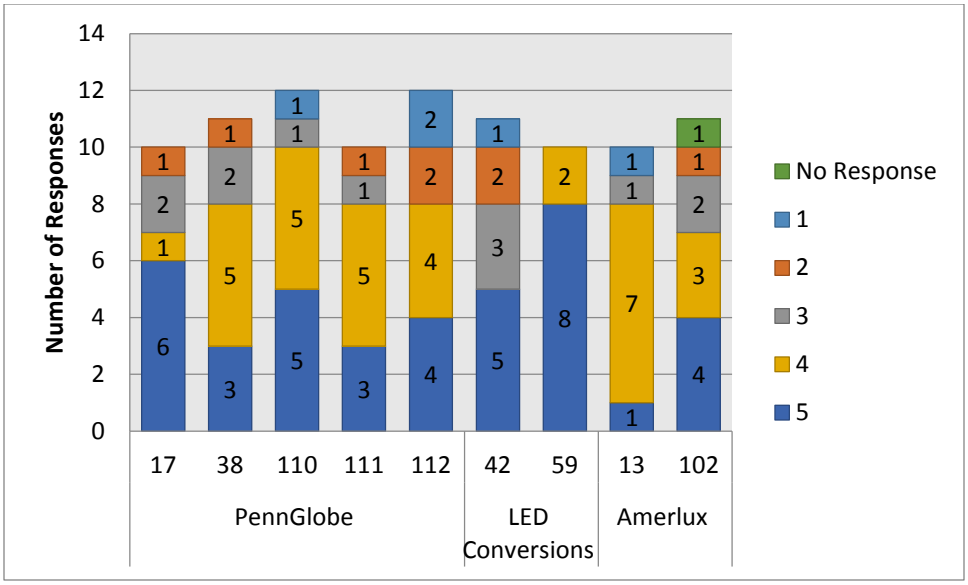


Figure 30 Please indicate your opinion of the following LED characteristics. (Brightness)

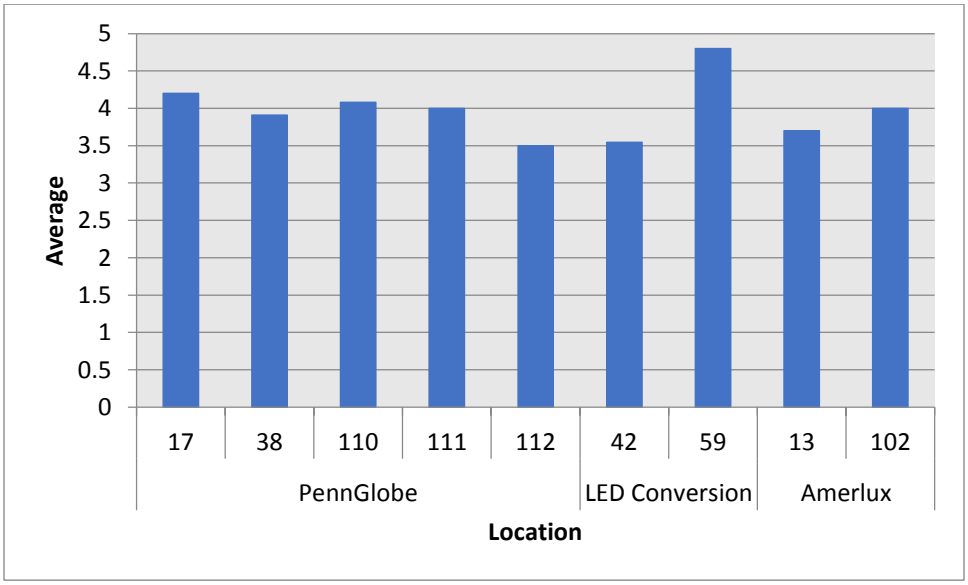


Figure 31 Average Value for Brightness at Each Location

The public opinion of the color of the LEDs is compared in Figure 32. The responses varied on the color of the streetlamps at the different locations. The color of the LED from Amerlux was positively accepted by the public. Figure 33 indicates the average value of the responses on the color of the LED indicating that certain PennGlobe and LED Conversions were least liked with the lowest averages.

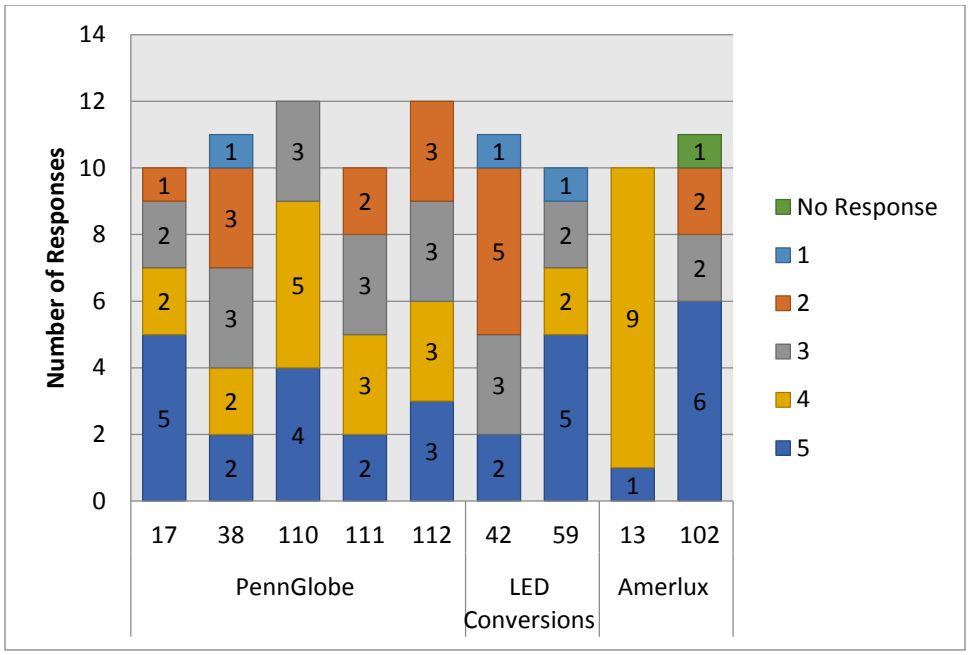


Figure 32 Please indicate your opinion of the following LED characteristics. (Color)

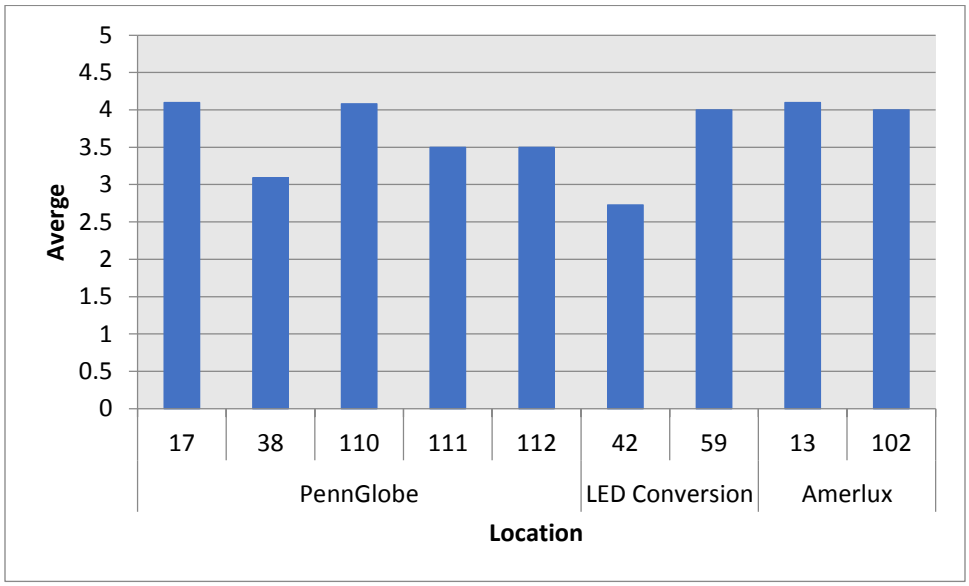


Figure 33 Average Value For Color at Each Location

Finally, Figure 34 shows the responses for the ranking on the general visibility of the LED lights or the amount of light emitted improving the visibility of the surrounding area. The average values for each location are provided in Figure 35 to indicate that the overall rating for the visibility was close to a four.

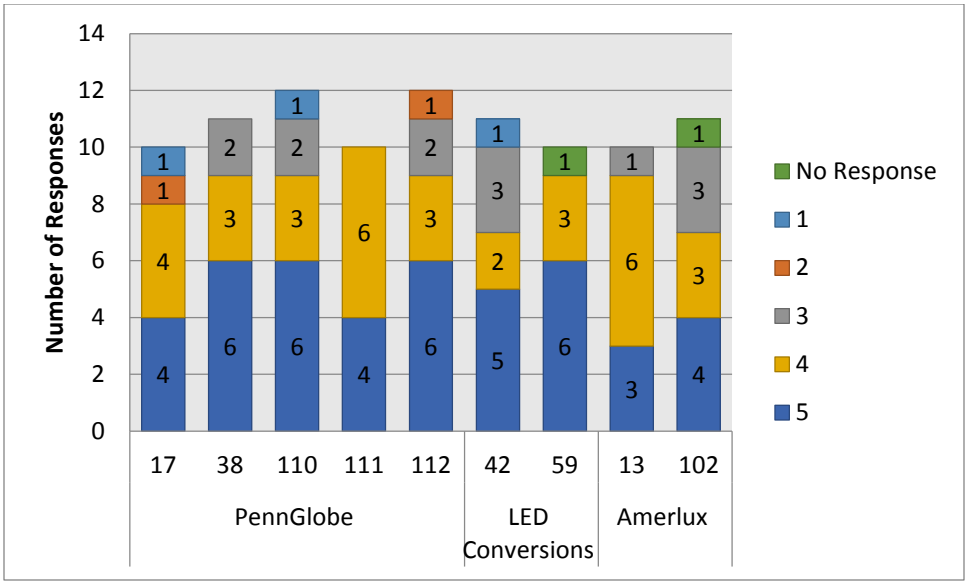


Figure 34 Please indicate your opinion of the following LED characteristics. (General Visibility)

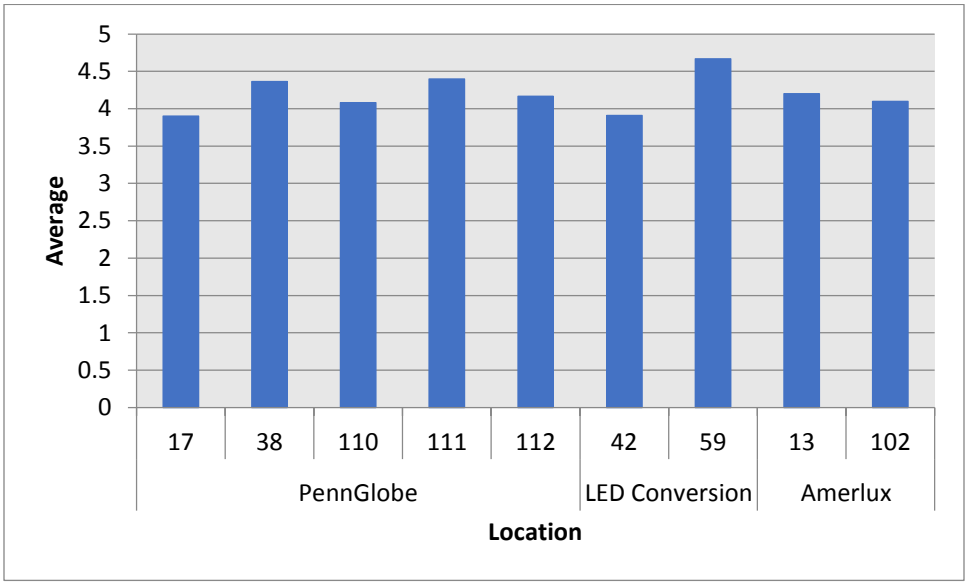


Figure 35 Average Value for General Visibility at Each Location

The public was surveyed on their opinion of the brightness and color of the LED compared to those characteristics of the existing HPS streetlamp bulbs. The responses to the questions that asked which the respondent preferred the LED or HPS, are visualized in Figure 36 and Figure 37. In regards to the color emitted by the streetlamps according to Figure 36, about 63% of the respondents said they preferred the LED color over the color of the existing HPS

bulb. Similarly for the brightness according to Figure 37, about 75% of the public surveyed preferred the LED over the existing HPS.

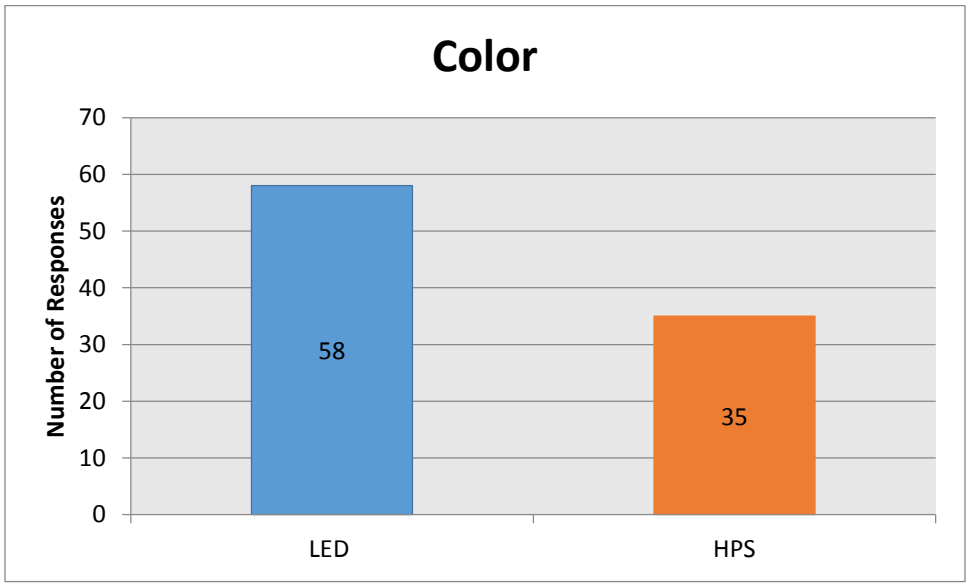


Figure 36 "Which streetlight color do you prefer?"

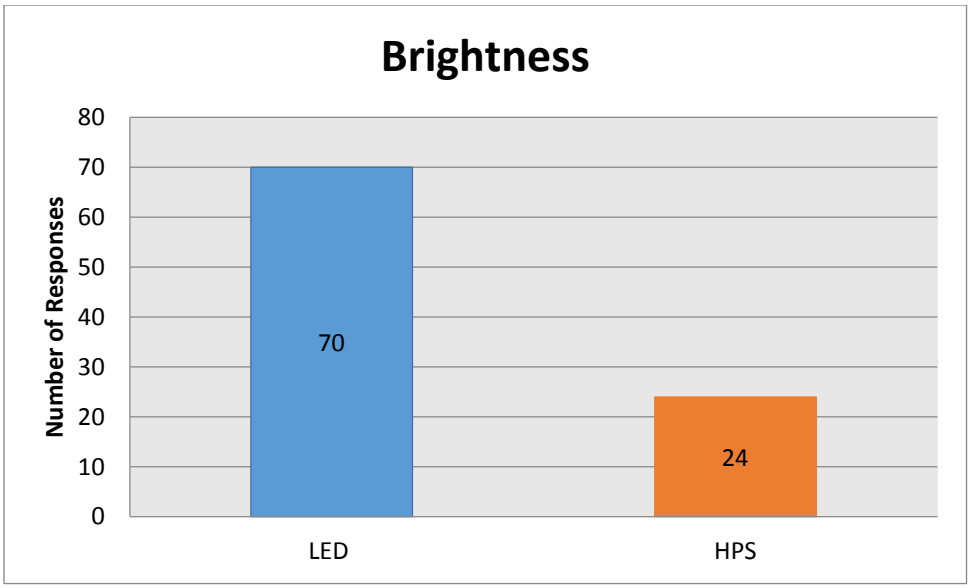


Figure 37 "Which streetlight brightness do you prefer?"

4.4.2 QR Code Surveys

The QR code surveys were placed on visible signs around the posts of each LED pilot streetlamp location. However, the responses from these surveys were low due to the need for a

QR code reader on a cell phone. There was only one QR code survey completed for streetlamp location 42. The purpose of this survey was to identify opinions of the specific location and to also identify that streetlamp as one of the LED pilot locations. Therefore, the rather low responses were expected but the purpose of the signs were fulfilled by visually identifying the locations to the public that walked by.

4.4.3 Online Survey

The online survey was completed by 28 individuals that received the link to the survey through email distribution by Lauren Sinatra, Nantucket Town Association, ReMain Nantucket, and other stakeholders supplied with the survey link or found the survey on the decorative streetlamp webpage on the Town website.

The main question on the online survey, absent from the in-person surveys, was the ranking question asking the public to, "Please indicate the importance you would place on the following reasons for replacing the existing HPS streetlights with LED lights." The team calculated the mean of each category in the question to determine the average response from the three-value scale. The average values, as graphically displayed in Figure 38, ranged from about 2.26 to 2.42. Surprisingly, the reasons with the two highest average values were "Uniformity Between Various Streetlamps" and "Reduced Light Pollution" instead of those reasons that centered around the decreasing of energy use and costs.

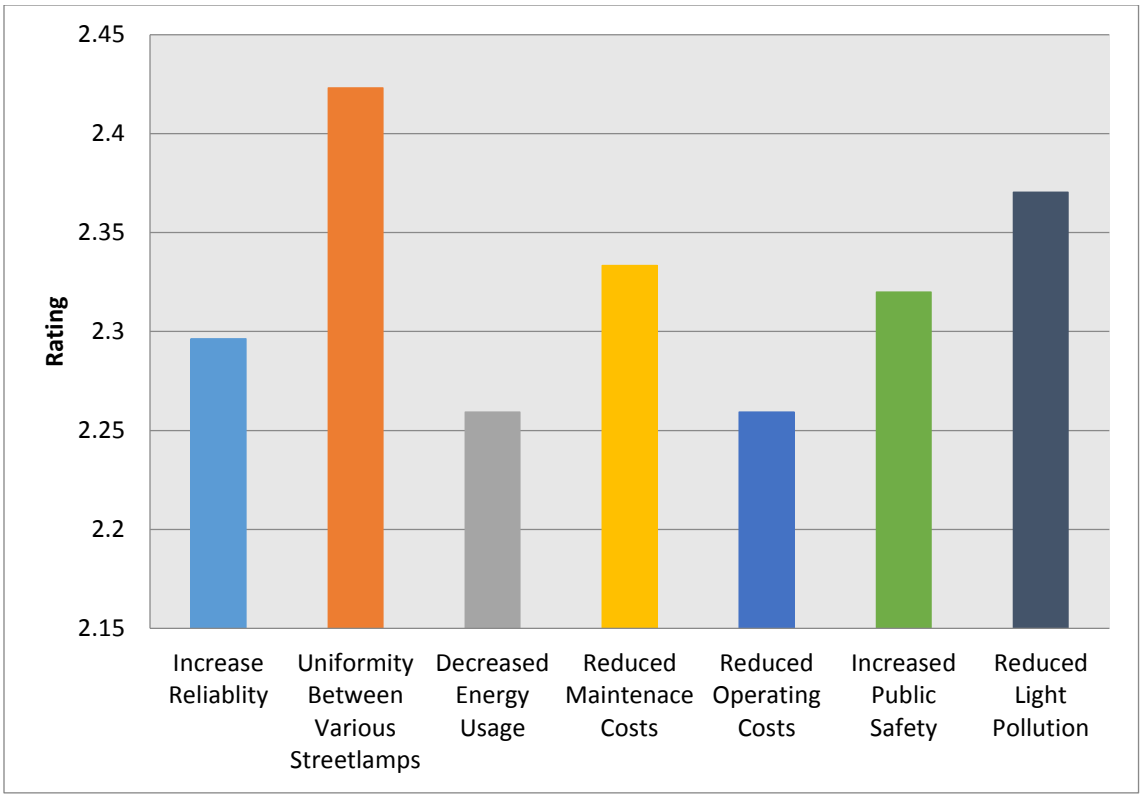


Figure 38 "Please indicate the importance you would place on the following reasons for replacing the existing HPS streetlights with LED lights."

4.4.4 Cumulative Survey Questions

Across the two main surveys, site-specific survey and online survey, we asked a few of the same questions that were important for our understanding of the public's opinion of the street lighting in the downtown core historic area and on the potential LED conversion of the decorative streetlamps. These questions were included in both surveys to increase the sample size and because they did not focus on the specific LED pilot location but the street lighting in general.

The first general question asked the respondent to indicate if they believed the amount of street lighting in the downtown area was adequate. Figure 39 indicates that 50% or 62 individuals who completed the survey thought there was not enough light for the downtown area streets, while 40% or 50 individuals believed that the amount of lighting in the downtown area was acceptable.

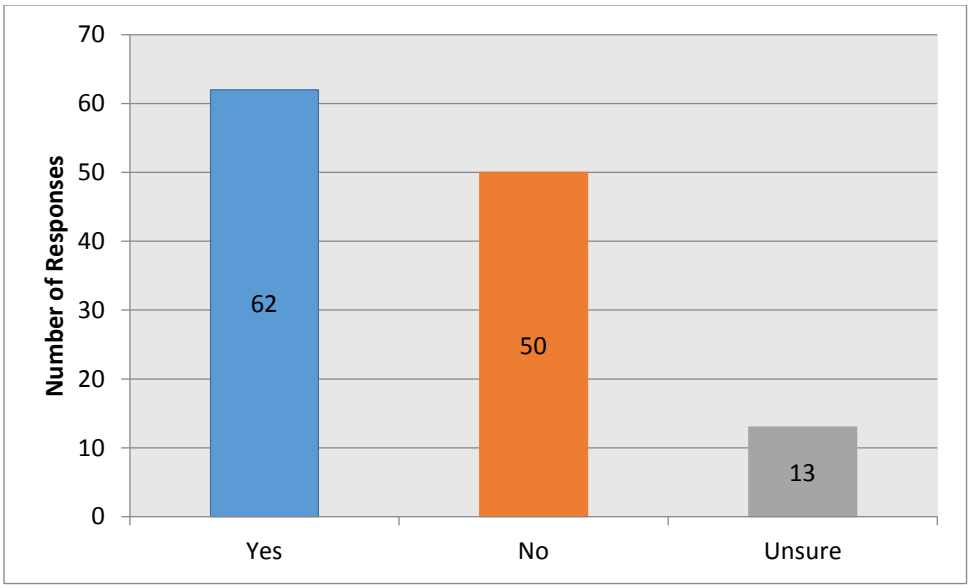


Figure 39 "Do you think the amount of lighting in downtown is adequate?"

In addition, the surveys asked if the respondent lived or worked in the downtown area. Of the 82 respondents that indicated "Yes" for either living or working in the downtown area, there was an almost equal number of people that answered "Yes" and "No" as seen in Figure 40. The comparison was pertinent because those respondents that lived and worked in the downtown area were consistently exposed to the streetlamps and able to make a more educated answer on whether the amount of light in the downtown area was adequate.

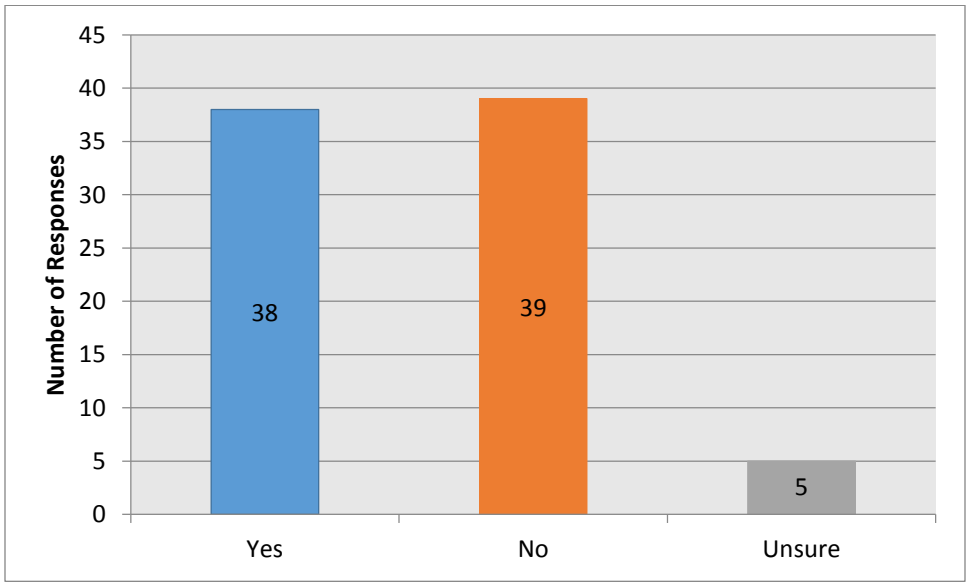


Figure 40 "Do you think the amount of light in the downtown area is adequate?" (Live/Work Downtown Area)

For the survey question that asked if additional Town resources should be budgeted to improve the condition and regular maintenance of the decorative streetlamps, there were 66% of those who completed the survey that agreed that more resources should be given to improve the physical condition of the streetlamps (Figure 41).

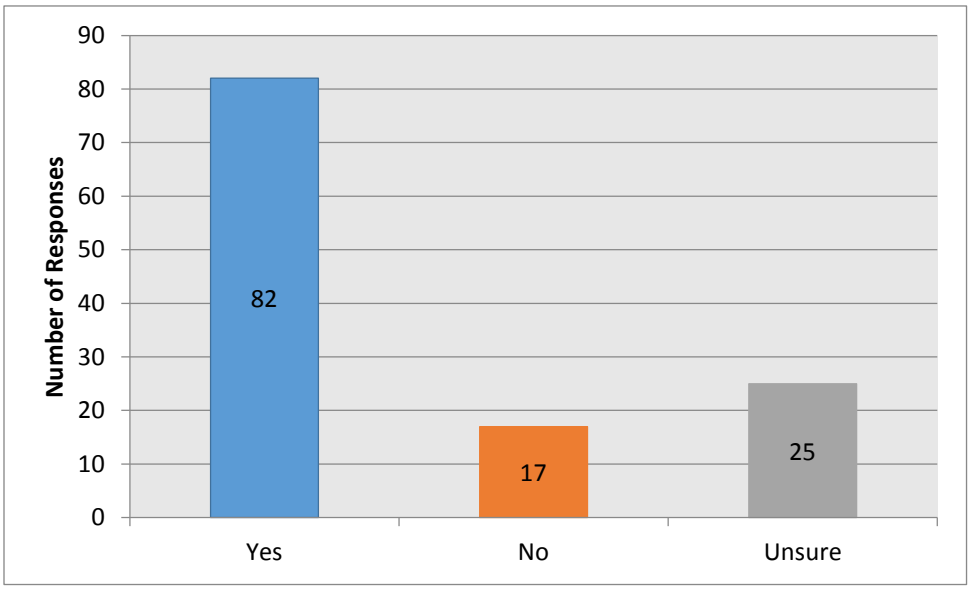


Figure 41 "Should additional Town resources be allocated to improve the conditions and regularly maintain the streetlamps?"

Another question asked on both surveys was if the individual noticed any of the LED retrofits that were installed prior to taking the survey and being informed that LED lights had been installed in select streetlamps. Figure 42 shows that 60% had not identified the pilot locations and 40% had identified the LED lights. This indicated that three-fifths were unable to notice the LED lights installed which could be attributed to the respondents' inability to note the difference between the installed LED and current HPS or other reasons such as being a visitor who just came off the ferry.

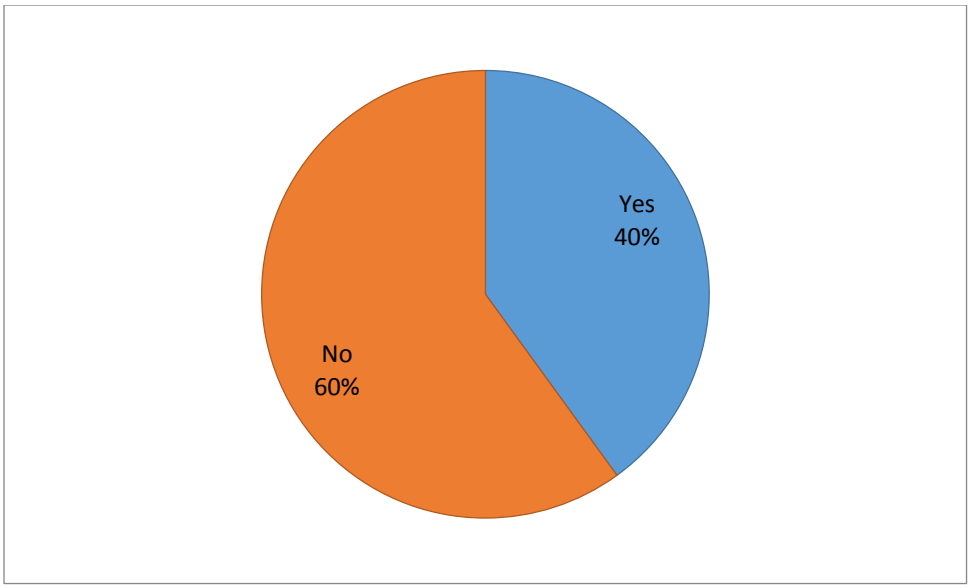


Figure 42 "Have you noticed any of the LED lights?"

The question that asked if the individual would support an LED conversion project is an important final question on the surveys that was of interest to the Nantucket Energy Office. However, the addition of "reduce electricity usage" and "save on costs associated with frequent maintenance" influenced the person taking the survey toward supporting the LED conversion. Overall, Figure 43 displays that 90% of the public surveyed would support the LED conversion, which could be largely due to the positive reasons included within the question. The survey responses outlined above support the final recommendation on the determined desirability of the public supporting the LED conversion based on their answers.

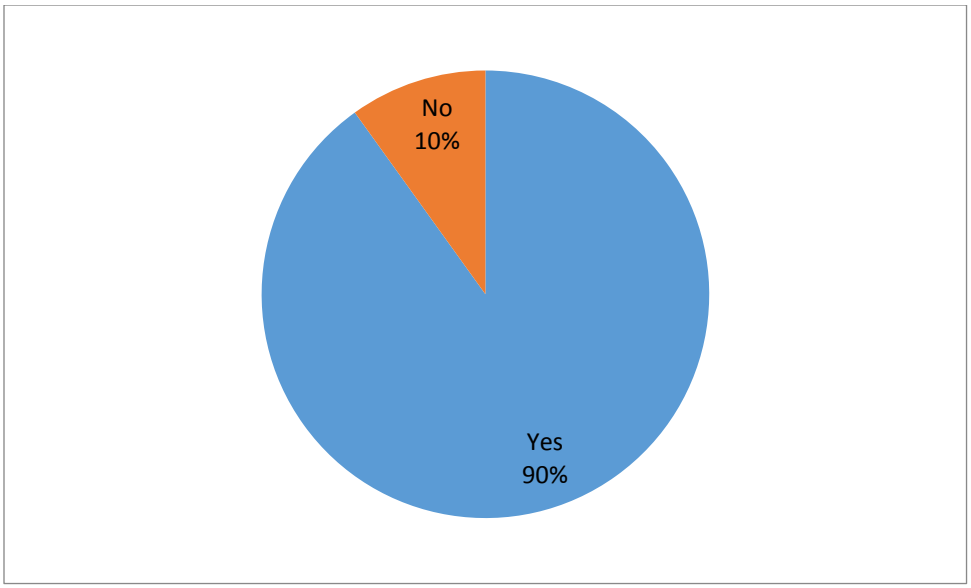


Figure 43 "Would you support a LED conversion project if the Town was able to reduce electricity usage and save on costs associated with frequent maintenance and repairs?"

4.5 Economic Analysis

This section discusses the overall economic analysis for the different scenarios that the Town could decide upon. One scenario focused on the current state the Town was paying to supply and maintain the streetlamps, and the three other scenarios were based on the three LED companies. The National Grid S-3 Option B and S-5 were compared to calculate the difference between the two tariff rates. The overall comparison discussed the cost for the retrofits, installation, and shipping that each company proposed for a potential LED conversion. With all the components calculated, we recommend which scenario will benefit the Town most financially on an annual basis.

The cost of electricity supplied to the 199 decorative streetlamps for the 2014 fiscal year was determined from the monthly National Grid bills and totaled $14,251.73. The team also calculated the current maintenance costs based off the 2014 fiscal year from Ryder Electric and PennGlobe invoices and the of maintenance costs was $35,436.75. As a combination, the Town spent $49,688.48 on maintaining and supplying power to the streetlamps.

4.5.1 National Grid Tariff Rate

As stated in Section 3.4 of the methodology, the tariff rate for an LED conversion would change to the National Grid S-5 rate from the current S-3 option B that applies to the HPS bulbs. In order to compare the new tariff rate energy cost with the current 2014 fiscal year energy cost for the decorative streetlamps, we calculated the existing total annual cost based on the "Supply Services" and "Delivery Services" charges in the National Grid bills, which equaled $10,004.27. The "Facility Charges", which are the costs for maintenance performed by National Grid, incorporated in the energy cost are not used to determine the estimated total annual energy savings because under the S-5 rate these charges are not applicable. With the S-5 tariff rate, National Grid would no longer be responsible for any maintenance on the streetlamps including their prior responsibilities of changing the bulbs and photocells. The Town would be accountable for the repairs transferred along with any current maintenance cost that might come from Ryder Electric and other contractors. Therefore, the Town would have to consider the possible cost of those additional maintenance tasks National Grid had performed and included in the "Facility Charges" of the S-3B rate. The calculation of the estimated S-5 tariff rate for the prospective LED conversion, using the new retail delivery rate of $0.06207 and the annual usage of 104 kWh, resulted in $1,284.60 for the total annual cost of energy. As a result, the estimated total annual energy cost savings was $8,719.67.

4.5.2 Company Conversion Costs

The three LED pilot retrofit companies supplied different kits with varying degrees of specifications at the nine pilot locations. Through communication with representatives from these companies, we obtained specifics of the warranty and costs. The general information is compared for each scenario below in Tables 7 through 10. Each of the LED companies, Amerlux (Section 4.5.2.1), PennGlobe (Section 4.5.2.2), and LED Conversions (Section 4.5.2.3), are discussed further on their retrofit costs and additional services offered.

The National Grid incentive provided for each retrofit was received from the representative from National Grid and was based off the total cost of the conversion project. We applied the incentive of $75.00 per fixture as seen in Table 10 for each of the company scenarios to determine the final total project cost the Town would have to pay.

Company	Color Temperature	Wattage	Warranty (LED)	Warranty (Driver)
Amerlux	2400K	41W	10 Years	5 Years
LED Conversions	2700K	30W	5 Years	5 Years
PennGlobe	4000K (with Amber Diffuser)	37W	5 Years	5 Years
PennGlobe	4000K	37W	5 Years	5 Years
PennGlobe	3000K	37W	5 Years	5 Years

Table 7 Specifications of Pilot Retrofits

Company	Cost/ Boulevard Retrofit	Cost/ Philadelphia Retrofit	Number of Boulevard Fixtures	Number of Philadelphia Fixtures	Total Retrofit Cost
Amerlux	$379.00	$379.00	60	139	$75,421.00
LED Conversions	$229.94	$229.94	60	139	$45,758.06
PennGlobe	$575.00	$525.00	60	139	$107,475.00

Table 8 Retrofit Costs for Each Company

Company	Installation Time/ Boulevard Retrofit	Installation Time/ Philadelphia Retrofit	Installation Cost	Total Installation Cost
Amerlux	60 Minutes	60 Minutes	$165/hr	$32,835.00
LED Conversions	40 Minutes	40 Minutes	$165/hr	$21,890.00
PennGlobe	30-40 Minutes	15-20 Minutes	$25,000	$25,000.00

Table 9 Installation Costs for Each Company

Company	Incentive per Retrofit	Number of Fixtures	Total with National Grid Incentive	Shipping Cost	Overall Total Cost	Total Cost/ Retrofit
Amerlux	$75.00	199	$60,496.00	-	$93,331.00	$469.00
LED Conversions	$75.00	199	$30,833.06	$1,000.00	$53,723.06	$269.97
PennGlobe	$75.00	199	$92,550.00	$5,475.00	$123,025.00	$618.22

Table 10 Overall Costs for Each Company

4.5.2.1 Amerlux

Amerlux had produced a custom LED specifically for the retrofit project in Nantucket. The cost per retrofit was $379.00 for both fixture styles. Their LED was created to produce one of the lowest light color temperatures, 2400 K, out of all the LED companies shown in Table 7. They had informed us that it would take approximately four to six weeks to produce nearly 200 retrofit LEDs and chose to have an outside contractor, much like Ryder Electric, install their retrofits rather than a representative from their company. From the install with Ryder Electric we observed an install time of around 60 minutes per each streetlamp style. After gaining experience working with these LED kits, the installation time would likely decrease. As seen in the Tables above, the full Amerlux project was priced at $93,331.00 which includes the shipping cost to the island and the incentive from National Grid as well.

4.5.2.2 PennGlobe

PennGlobe has been supplying the Town all the decorative streetlamps for over 30 years. They provided five different LED retrofit pilots with color temperatures of 3000 K and 4000 K, some with an amber diffuser. The cost per retrofit from PennGlobe varied based on the type of fixture. The Philadelphia fixture style was priced at $525.00 while the Boulevard fixture was priced at $575.00. Since some of the Boulevards have translucent domes, the retrofit included the aluminum dome to prevent light pollution which explained the price difference. The overall conversion cost including all components would cost $123,025.00. The amount of time to install the retrofits in the Boulevard fixture would double due to the addition of installing the aluminum dome. There is the option of replacing the fixtures with those equipped with LEDs to avoid installing the fixture and LED retrofits separately. Also, the PennAVATE option would refurbish all lampposts and fixtures, which would be an additional $35,000.00. Although they stated that the LEDs and drivers are under five years warranty, they are willing to negotiate to extend this period for the Town. There have been cases of inconsistency in the specifications of streetlamps installed in the past as a result of different people ordering items at different times. To prevent this from occurring for future replacements, all orders should specify the same model and components for Nantucket.

4.5.2.3 LED Conversions

LED Conversions is a company in Salem, New Hampshire that has been providing LED retrofits for towns and businesses all across the northeast. Their retrofit kit produced a color temperature around 2700 K and was all manufactured in the United States with an exception to the driver that was made in China. The company sent out two representatives to complete their retrofit installs and we were able to observe an install time of around 40 minutes for each streetlamp style. Mac Lummis, president of LED Conversions, was able to inform us that the cost per retrofit was $229.94 that included the LED board, the driver to control the LED, and the diffuser to shield the LED. The full LED conversion project cost was around $53,723.06 if installed by Ryder Electric. In the event there is an LED malfunction, Lummis informed us that the drivers have about a 1% failure rate over a 5 year warranty period, the defective parts are replaced at no charge. The more expensive LED light boards have "circuitry built in to protect them from defective power supplies," such as a less expensive driver. The LED could cycle on and off, which happens when the supply voltage drops below the specified voltage of the LED board and only turns back on when the supply voltage reaches the recommended voltage for the LED (Mac Lummis, personal communication, December 5, 2014).

4.5.3 Payback Periods

Based on the tariff rate changes and company conversion costs the team was able to calculate various scenarios for payback periods. The section is broken down into the energy savings payback periods and the payback periods of various reduced maintenance costs.

4.5.3.1 Energy Savings Payback Periods

The changes between tariff rates that accompany an LED conversion project from the S-3B rate to the S-5 rate would save the Town $8,719.67 in energy costs annually. With this information and the costs for the total conversion, the team was able to determine the payback periods based solely on the money saved in energy costs for each company as seen in Table 11. If the conversion was completed using Amerlux, LED Conversions, or PennGlobe, the amount of years for the Town to pay off the initial conversion costs would be about 11, six, or 14 years respectively.

Company	Total Overall Conversion Cost	Savings Per Year on Energy Cost	Payback Period (Years)
Amerlux	$93,331.00	$8,719.67	10.70
LED Conversions	$53,723.06	$8,719.67	6.16
PennGlobe	$123,025.00	$8,719.67	14.12

Table 11 Payback Periods from Energy Cost Savings

4.5.3.2 Maintenance Payback Periods

Since the records of maintenance repairs are incomplete and it was often unclear which repairs were performed by National Grid or Ryder Electric, the team was only able to base the calculations on the maintenance invoices from Ryder Electric and PennGlobe for the fiscal year of 2014. The Town spent $35,436.75 on maintenance by Ryder Electric for various repairs, which were not specified in the invoices. There was possible overlap in these repairs that Ryder Electric charged for when National Grid was already paid to perform those within the S-3B tariff rate. In addition, we did not have the proper information pertaining to the maintenance costs of the past year, thus limiting us to making an assumption based on this general annual cost that may not reflect the average yearly maintenance cost for the streetlamps.

We are also limited by remaining uncertainties regarding the types and amount of maintenance required for LEDs. With the installation of LEDs in the streetlamps, the maintenance costs could fluctuate from the current cost depending on the variables that cannot be predicted. The maintenance cost could fall if the LED technology proves to be as durable and reliable as predicted. The LED companies claimed that this technology would last longer compared to the current HPS bulbs that last roughly 24,000 hours as mentioned in Section 2.5. In theory, the amount of required maintenance would decrease and the Town would not have to inherit the costs previously associated with the "Facility Charges" from National Grid.

However, since the LED technology is relatively new there is a lack of real-world data to support the claims of the reliability and lifespan of LEDs. This is especially true given the unique environment of Nantucket with high winds, high humidity, and the salt air. Maintenance costs may well decline due to improved reliability and durability, but we do not yet know if this will actually be the case on Nantucket. Furthermore, with the shift to the S-5 tariff, the Town will take on additional repair costs formerly incurred by National Grid, such as when a photocell fails. Therefore, the Town should conduct additional research to determine more precisely the

likely reliability of LEDs in the Nantucket environment and to better estimate the expected annual maintenance costs.

As an example the team used the available maintenance cost records from the 2014 fiscal year to simulate the possible payback periods under different scenarios of projected annual maintenance costs for LEDs (Table 12). These payback periods were calculated by taking the overall cost of the company conversion and dividing by the total annual savings which includes savings from the maintenance cost, "Facility Charges" and the energy cost. In the future, the Town could use this formula for calculating the payback period when more clarification on the maintenance cost for LEDs is available.

% of 2014 Maintenance Cost	Projected Maintenance Cost per Year	Payback Period (Years)		
		Amerlux	LED Conversions	PennGlobe
0%	$0.00	1.93	1.11	2.54
25%	$8,895.19	2.36	1.36	3.11
33%	$11,812.25	2.55	1.47	3.36
50%	$17,718.38	3.04	1.75	4.01
100%	$35,436.75	7.20	4.14	9.49
125%	$44,295.94	22.72	13.08	29.95

Table 12 Maintenance Payback Periods

This table illustrates seven possible maintenance scenarios to calculate the payback periods that range from no maintenance cost to an increase in maintenance cost. The chart represents the possible payback periods depending on what percentage of the 2014 fiscal year maintenance bill is applied to future years. If the maintenance increased to a certain point, then the Town would not be able to pay off the conversion based solely on the savings from the tariff rate change and the maintenance cost. On the other hand if in future years the cost of maintenance is three quarters less than it was in the 2014 fiscal year then the Town would be spending only $8,895.19, which is 25%, and the payback periods for Amerlux, LED Conversions and PennGlobe would be 2.36 years, 1.36 years, and 3.11 years respectively. These are generalizations based on the available data that should be used as a resource when determining the actual payback periods of an LED conversion.

Chapter 5: Conclusions and Recommendations

In this section, we outline our numerous conclusions through working on the inventory, interactive map, and LED pilot project of the Town-owned decorative streetlamps. From these conclusions we were able to present various recommendations to the Town.

Conclusion 1: The team identified that the discrepancy in the actual number of streetlamps was due to a lack of a system to record the details of the streetlamps. The team created an inventory database for the streetlamps, an interactive map for the public to communicate with the officials, a reporting form to record the reported issues that need to be addressed, and the maintenance form that keeps track of the repairs done on the streetlamps. These systems function independent of each other due to limitations in the software. With these systems and proposed updating process, they might become useless if they are not constantly updated and maintained. From the interviews with representatives from the DPW, National Grid, and Ryder Electric, we found that if multiple people are involved in the maintenance process, each party might assume the others were updating the information resulting in the possibility of the systems becoming obsolete.

Recommendation 1: The inventory database, interactive map, streetlamp issue reporting form, and maintenance form should be maintained and updated by one individual in the town.

One individual should have the responsibility to update the inventory database and interactive map to reduce the chances of the systems not being updated properly. This individual should also complete the maintenance form for the repairs completed on the streetlamp from information received through communication from National Grid and invoices from contractors. However, in the future, the maintenance form should be completed by National Grid and contractors at the time of repairs. We recommend that the Town officials involved with the decorative streetlamps should appoint a person, who has basic computer skills and knowledge of the streetlamp maintenance process as the Town Streetlamp Administrator to organize the information effectively and work conjunctively with the DPW.

Conclusion 2: Prior to the project, there was no established process of how to resolve reported issues. The public reported problems to National Grid or DPW through email, phone call, or the SeeClickFix application. By protocol, National Grid was the first respondent to address the issue with the streetlamp but only completed the repair when it involved the electricity supplied to the post, changing of the lighting bulb, or replacing the photocell. However, the crewmen did not always effectively communicate the problems repaired with the Town. On occasion, Ryder Electric would perform repairs on the streetlamps without approval from the Town officials and then send ambiguous invoices to the DPW. The Town would pay the bills without knowing who had requested the repair and whether the repair had been completed. Through all these steps, there was lack of communication among National Grid, DPW, Ryder Electric, and the public.

Recommendation 2: The Town should define a clear chain of communication for the process of maintaining the streetlamps and responding to complaints.

We recommend that the Town should define a chain of communication that would prevent confusion among the parties involved when an issue with the streetlamp is reported. The reporting form would notify all appropriate stakeholders when a problem is reported and who requested the repair. From there, National Grid would respond to functionality issues and emergency response requests while DPW would respond to structural or environmental issues. To keep everyone updated on the current status of each streetlamp, the TSA would be responsible for updating the inventory and interactive map. Each individual part of the chain of communication would have a defined responsibility to prevent any detail or action from being overlooked or neglected. This would allow the whole to work in an orderly fashion to efficiently fix any urgent or minor problem that might regard the public's safety and concerns.

Conclusion 3: Although the team chose Google My Maps as the basis for the Town's interactive map due to its features, it still has many limitations. The systems, interactive map and inventory database, coexist parallel to each other, but they both require manual input in order for the information to correlate. Unfortunately, this increases the chance for the systems to not be in sync due to potential human error. In respect to the "Current Status" field in My Maps, the TSA needs to type out the status of the map exactly as shown in the map key in order to have the icon

change to the appropriate color. Also, when a reporting form is submitted online, the "Current Status" on the map and in the inventory does not change automatically resulting in the TSA having to manually update them separately.

Recommendation 3: The Town should explore ways to upgrade and improve the streetlamp database to address current limitations.

Due to limitations with the software used for both the inventory and map, we recommend that the limitations be resolved with future upgrades to the software. The inventory database and interactive map should be linked for automatic updating. If the two types of software were linked, then the TSA would only need to update one system and the other system would automatically change, which is an easier way to manage data. We suggest a dropdown menu, which is currently not an option, be utilized for the "Current Status" field on the interactive map. Since it is vital that the wording and capitalization for the inputs be exact in order for the correct icons to appear to represent a consistency in the statuses, these dropdown menus should be added. In addition, the team proposes that the "Current Status" and icon on the map should automatically change when a reporting form is submitted to lessen the work for the TSA. This would allow the public to know if the issue has been reported immediately without waiting for the TSA to manually update the information, which could be delayed after the form has been sent. The interactive map should be upgraded and improved to incorporate extended features for official purposes, such as color coding for specific groups. This would allow National Grid, Ryder Electric, and DPW to focus on their responsibility without confusion on what issue they need to resolve, eliminating gaps in the chain of communication.

Conclusion 4: Through the interviews, survey responses, and general observations by the team, we concluded that the conditions of the Town-owned decorative streetlamps and amount of light in the downtown area could be improved. The results of inventorying the condition of all the streetlamps for the database revealed that the streetlamp fixtures and posts were in varying degrees of disrepair and neglect. The designs of the streetlamps were not consistent with two different fixture styles, Boulevard or Philadelphia, and other different accessories that were purposely made dissimilar at initial installation. There was, excluding the streetlamps that were missing fixtures or posts, 73 Boulevard style fixtures and 107 Philadelphia style fixtures and a

range of four different types of chimneys. The condition of the streetlamps ranged from minor issues of missing post numbers and dirty fixture lens to major repairs of leaning posts and exposed wires. Over half of the responses to the online and in-person surveys answered that more Town resources, both monetary and personnel, should be allocated to improve the conditions and regularly maintain the streetlamps. The adequacy of the amount of streetlamps in the downtown area was a discussion topic during the interviews. The initial installations of the streetlamps were sporadic and were centralized on more populated streets in order to preserve the historic nature. Various stakeholders expressed their concern for lack of light in certain areas of downtown, where few to no streetlamps were located. These concerns stemmed from the aspect of safety due to the uneven sidewalks throughout downtown and the perceived higher occurrence of crime in poorly lighted areas. Through both the survey responses and interviews, it was indicated that the public was more supportive of uniformity of the streetlamp design, which consisted of the type of fixture and chimney accessories for all the decorative streetlamps.

Recommendation 4: The Town should improve the conditions of the streetlamps through a scheduled maintenance plan and install more streetlamps to increase the amount of lighting in the downtown area.

In response, the team recommends that the Town create a scheduled maintenance plan for the decorative streetlamps and install more streetlamps in areas identified as inadequately lit. A maintenance plan should be utilized to continually assess and address the issues with the streetlamps. Maintenance of the streetlamps should occur on a regular biyearly basis. This plan should include a regular cleaning of the lamps, painting of the post and fixtures when needed, and addressing the damages. With this regularly scheduled maintenance plan, the condition of the streetlamps should improve both aesthetically and functionally. We recommend that the DPW should take more responsibility in maintaining the structural repairs that do not have to be addressed by an electrician or National Grid. Additional streetlamps should be installed in areas that are lacking street lighting and ambient light from the surrounding businesses. Specifically, more lighting should be present in areas such as lower Broad Street, upper Main Street, Orange Street, and the side streets that include Chestnut Street and Salem Street. With the addition of new streetlamps to the inventory, the Town should choose a consistent design for the type of streetlamp fixture and other components that should be made the standard for installations on

Nantucket. The recommended specifications for new streetlamps installed and for replacing the existing streetlamps would be fiberglass streetlamp posts, Boulevard fixtures, and powdered chimneys. These recommendations are based off the results of inventorying the current conditions, which identified the features of the streetlamps that were easier to repair, and the popular opinion from the stakeholders, which identified the aesthetic appeal of the features. In addition, a minor recommendation would be to renumber all the Town-owned streetlamps based off the street location and area of downtown. This would give the Town the ability to incorporate new additions smoothly and allow maintenance crews to identify the locations of the streetlamp based off the post number.

Conclusion 5: When the team conducted the different surveys, we noticed a pattern in the public responses concerning their knowledge about LEDs in general and in particular the ones installed on Nantucket. While we were conducting the in-person surveys, some people were unsure what LEDs were so we had to provide a brief description in order for them to complete the survey. Some were not familiar with the benefits that accompany the technology, such as a reduce in electricity usage and high efficiency. Even on the public comments on the online survey, there were some misconceptions that people had regarding the pilot LED lights installed. Since the online survey did not require the individuals to be present on the pilot sites, they might not have seen the warm color temperatures being piloted. Therefore, some comments addressed how white and unattractive LEDs were. One comment mistakenly stated that LEDs contain mercury, which could be harmful to the public if the LEDs are damaged, becoming exposed to the surroundings. However, that statement is not true since LEDs do not contain such substance, while the current HPS bulb does.

Recommendation 5: The Town should focus on educating the public on the technology behind LEDs.

Since there is still substantial public misunderstanding about LED technologies, the Town should implement a thorough public outreach effort in advance of implementing a full conversion of the streetlamps to LEDs. This would also let them know that LEDs come in warmer colors unlike the older models that leaned towards the white or blue colors. Once the

public understands more about LEDs, they might be even more in favor of the full implementation in the decorative streetlamps.

Conclusion 6: In the year 2013, the Town of Nantucket used 4,175 hours of lighting to operate the nearly 200 decorative streetlamps in the historic cores of the island, spending $10,004.27 on electricity from National Grid according to the S-3B tariff rate. A conversion would result in the change to the S-5 tariff rate which would amount to $1,284.60 annually for electricity, saving the Town $8,719.67. In additional costs the Town spent $35,436.75 on maintenance of the decorative streetlamps in the 2014 fiscal year. Increasing electricity rates and the possibility of a third National Grid transmission cable from the mainland would cost the Town upwards of 80 million dollars in addition to the annual costs. The Nantucket Energy Office supported the LED Streetlamp Pilot Project to determine if the conversion from HPS bulbs to LED retrofit lights could alleviate some of the financial and energy burdens of the Town.

Recommendation 6: The Town of Nantucket should expand upon our research in considering an LED conversion.

The Town should go through with the process of an LED conversion for the decorative streetlamps after further investigation. From the surveys it was apparent that the public was accepting of the possibility of converting the HPS bulbs to LED retrofits to gain the benefits while preserving the historic appeal of the Town with the warm color temperature. The process of the conversion should be done all at once, not in steps when lights fail, to immediately receive the effects of reliable lighting which is urgently needed in areas throughout the Town. However, the conversion should be done in groups, preferably by location. Through this process the highest level of uniformity will be achieved and other final records and maintenance may be done throughout the installations. With LEDs, the cost of maintenance for the town should drop due to the reliability of the new technology, the cost of electricity would lessen with the tariff change, and energy usage would decrease by two thirds. However, we recommend the Town should continue gaining public feedback on the LEDs and look further into the economics, specifically the change in tariff rate and assumed drop in maintenance costs, revolving around the change from the current lighting to LEDs.

Conclusion 7: Throughout the project the team conducted surveys on all the pilot retrofits. These surveys displayed that the public was in favor of the LED lights in every aspect; color, brightness, and the conversion as a whole. In choosing which color temperature to recommend, the team analyzed the public's opinions from the surveys based on the different options. From the survey results the team concluded that PennGlobe's 4000 K retrofit with the amber diffuser at location 17 and Amerlux's 2400 K retrofits installed in locations 102 and 13 were most favorably ranked by the public in regards of color. When ranked on brightness, the retrofit that the public liked most was LED Conversions's 2700 K in location 59.

Not only were the aesthetics important when regarding the LED conversion, but also the feasibility of the financials. PennGlobe's retrofit for a Boulevard fixture would cost $575.00 and a Philadelphia would cost $525.00. Amerlux's and LED Conversions' retrofits would cost $379.00 and $229.94 respectively. After including all the components in the calculations such as retrofit kit, shipping and installation, the overall conversion would cost $123,025.00 for PennGlobe, $93,331.00 for Amerlux and $53,723.06 for LED Conversions. Each company's warranties were similar, however the installation times varied. PennGlobe, who would do the installation themselves, would take between 15 to 40 minutes for each fixture. Both Amerlux and LED Conversions would use a third party contractor for the installs, such as Ryder Electric. Amerlux's retrofit kit took approximately 60 minutes for install and LED Conversions's took approximately 40 minutes.

Recommendation 7: If the Town of Nantucket implements an LED Conversion, we recommend the 2400 K retrofit kit supplied by Amerlux.

The team recommends Amerlux as the company for the LED conversion through considerations regarding the public feedback and financial aspects. The color temperature, 2400 K, was one of the highest ranked pilot sites when the public was surveyed. The overall cost is the middle price of the three companies, therefore the median payback period, but the aesthetics outweighed the cheaper price when compared to LED Conversions. The warranty of Amerlux's LED board was 10 years compared to the 5 year warranty offered by the other companies. The only apparent downfall the team could find of the Amerlux retrofit was the difficulty that Ryder Electric had installing it, which resulted in an extended install time. However since the product is

custom made for Nantucket, the retrofit will be modified for easier installation within the particular fixtures when manufactured, and with experience the installation time should decrease. The team considered the past relationship with PennGlobe and the possibility of the PennAVATE program when discussing the company's retrofit kit, but the public generally did not favor the brightness or color of these pilots and the price was the greatest of the three options. Our final recommendation to pursue the LED conversion utilizing the 2400 K retrofit kit provided by Amerlux incorporates all considerations that we obtained throughout the project.

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Appendix A: Interview Questions

Interview Preamble:
We are students from WPI working with the Nantucket Energy Office on determining the feasibility of implementing LED streetlights in the historic district of Nantucket. We would like to ask you a few questions pertaining to (insert topic here). Also, would you mind if we quote you in our final report, or would you prefer your comments remain anonymous? We will give you the opportunity to review any quotations prior to publication.

Representatives (Nantucket Town Association)

- General Background Questions
    - What is the background of the Nantucket Town Association?
    - What is the Nantucket Town Association's role in the community?
    - What is your association's past involvement with the decorative streetlights, if any?
- Concerns from Nantucket Town Association
    - As a homeowner's association, do you currently have any concerns about the street lighting in the downtown area?
    - What is your association's history with (exterior) LED lights? Have you received complaints regarding LED lights in general?
- Opinion on Streetlamps (Survey Questions)
    - Do you think the lighting in the downtown area is adequate?
    - What is your opinion on the condition of the streetlamps?
    - Should Town resources be allocated to improve the conditions and maintenance of the streetlamps?
    - Were you able to identify any of the LED retrofit pilot sites in downtown?
        - Did you have any general observations or initial thoughts on the LED lights?

        - What is your opinion of the brightness and color of the pilot lights you observed?
        - Do you think look of the LED lights are appropriate for the historic district?
        - Do you think the public would accept this change to LED lights in the historic downtown area?
    - Would your association be accepting of a conversion to LED streetlamps?
- Mapping Reporting and Public's Perspective
    - Have you or anyone you know attempted to report a street lighting issue?
        - What was your experience?
        - What improvements can you suggest?
    - Do you think having a process of reporting issues with the streetlamps on the Town's website be effective?
    - If an interactive map was included with the reporting process, what information do you think people would report?
    - As a follow up, what information should be included on the map for the public to view?
- Final Questions
    - Would you circulate our survey to the members of your association?
    - Do you have any final question or requests for clarification on our project?
    - Do you have any other people whom you think we should contact for this project?

Rachel Hobart and Melissa Philbrick (ReMain Nantucket)

- General Background Questions
    - What is the background of ReMain Nantucket?
    - What is the ReMain's role in the community? On energy and sustainability issues?
    - What vision did you have for the Nantucket Energy Office that caused you to sponsor the position?
    - What is your organization's past involvement with the decorative streetlights, if any?

- Concerns Historic Preservation and Conservation
    - What are keys factors that are important to preserve the historic district on Nantucket?
    - What do you think the public views as important features of the historic district?
    - What level of importance do you think the public places on the preservation of the historic district?
    - In regards to the music school project on 56 Centre St., if you feel comfortable, what was the selection process for the decorative Boulevard streetlamps? Why HPS bulbs with clear top? Did you look into potential LED lights?
    - Do you feel the current lighting (HPS bulbs) are appropriate color for the historic district?
    - Looking at our example of the LED from Amerlux, do you think this color of lighting will be suitable for the aesthetics preservation of the historic downtown area?
- Opinion on Streetlamps (Survey Questions)
    - Do you think the lighting in the downtown area is adequate?
    - What is your opinion on the condition of the streetlamps?
    - Should Town resources be allocated to improve the conditions and maintenance of the streetlamps?
    - Were you able to identify any of the LED retrofit pilot sites in downtown?
        - Did you have any general observations or initial thoughts on the LED lights?
        - What is your opinion of the brightness and color of the pilot lights you observed?
        - Do you think the public would accept this change to LED lights in the historic downtown area?
    - Would your organization be accepting of a conversion to LED streetlamps?
    - If you noticed a streetlamp being out or damaged downtown, would you know the process for reporting the issue?
    - As a resident of Nantucket, what information would you like to see in an interactive map of the streetlamps available on the Town website?

- Final Questions:
    - Do you have any final question or requests for clarification on our project?
    - Do you have any other people whom you think we should contact for this project?

Dr. Sarah Oktay (UMass Field Station and Conservation Committee)

- General Background Questions
    - What is your academic background and general involvement on the island of Nantucket?
    - What is your past experience with light pollution/dark sky initiative in Nantucket, if any?
- Concerns Regarding Lighting
    - Are there any current concerns with lighting affecting the environment on the island?
    - Regarding the streetlamps in the downtown area do you feel there are any negative impacts?
    - What is your opinion of the current condition of light pollution in the Town?
        - What are your thoughts on the relationship between LED's and light pollution?
- Opinion on Streetlamps (Survey Questions)
    - Do you think the lighting in the downtown area is adequate?
    - What is your opinion on the condition of the streetlamps?
    - Should Town resources be allocated to improve the conditions and regularly maintain the streetlamps?
    - Were you able to identify any of the LED retrofit pilot sites in downtown?
        - Did you have any general observations or initial thoughts on the LED lights?
        - What is your opinion of the brightness and color of the pilot lights you observed?
        - Do you think look of the LED lights are appropriate for the historic district?

        - Do you think the public would accept this change to LED lights in the historic downtown area?
        - Would you be in favor of a conversion of all the decorative streetlamps to LED lights?
- Final Questions
    - Would you be willing to circulate an online survey?
    - Do you have any final question or requests for clarification on our project?
    - Do you have any other people whom you think we should contact for this project?

Steven Holdgate (National Grid)

- General Background Questions
    - What is your role in the community, specifically with National Grid?
    - How long have you been residing on the island?
    - What are your past or current involvement with decorative streetlamps?
        - Were you directly involved in streetlamp installations?
- Streetlamp Maintenance
    - What has been the prior protocol for inventorying the streetlamps?
        - Does National Grid have their own database on the inventory of Town of Nantucket owned streetlamps?
        - We are creating an inventory database of the streetlamps, what categories of information would be helpful for National Grid to have access to?
    - What is the current maintenance process for the streetlamps?
        - What are the responsibilities of National Grid vs. Ryder Electrics in terms of maintenance?
        - Does National Grid have a scheduled maintenance plan for the streetlamps?
        - What is the protocol for troubleshooting issues with the streetlamps?
            - Specifically when a post is removed. Who made the decision, what was the communication, etc.?
            - Missing poles and fixtures?

        - What is the type of HPS bulbs that are used to replace an outage? Specifically, what is the wattage, color temperature, and how are these characteristics determined?
        - Does National Grid currently have a way of checking if the ground connections of the poles are functional?
        - What is the process of communication between:
            - Crew members and National Grid regarding a maintenance job?
            - National Grid, Ryder, and the Town?
        - How do you think overall communication can be improved?
        - Who should be responsible for updating and maintaining the inventory database within the Town?
        - The Town has acquired various new streetlights from private owners, how should these lights be numbered, maintained, and integrated into the system?
- National Grid's perspective on the installation of LED lights
    - Why would National Grid be interested in supporting the conversion of LED lights for the streetlamps?
    - What are some of the different tariff rates that contain reduced cost for LED conversion, specifically the S-5 rate?
        - What is the different company responsibilities for the different rates?
    - Do you have experience with the installation for LED lights in other towns? Specifically historic districts?
        - What are some of the complications you encountered and feedback from the public?
- Views/Opinion of the use of LED Streetlamps on Nantucket
    - In your opinion, is there adequate lighting in the downtown area?
    - Were you able to identify any of the LED retrofit pilot sites in downtown?
        - Did you have any general observations or initial thoughts on the LED lights?
        - What is your opinion of the brightness and color temperature of the pilot lights you observed?

        - Do you think color temperature and look of the LED lights are appropriate for the historic district?
    - Do you know about the previous use of Metal Halide light bulbs in the streetlamps?
        - What was the general color/color temperature?
        - What was the public reactions to the change to HPS bulbs?
    - Do you think the public would accept this change to LED lights in the historic downtown area?
    - What do you feel are people's opinion of LED lights in general?
- Final Questions
    - Do you have any final question or requests for clarification on our project?
    - Do you have any other people whom you think we should contact for this project?

Dave Fredericks

- General Background Questions
    - What is your role in the community, specifically at National Grid?
    - What are your past or current involvement with decorative streetlamps?
        - Were you directly involved in the prior lamp installation?
- History of Streetlamps
    - What was the reasoning behind the installation of different types of fixtures and pole style?
        - If the town was going to do a mass conversion of the streetlamps, which style of streetlamp would you prefer? Boulevard or Philadelphia?
    - What has been the prior protocol for inventorying the streetlamps?
    - What would be important categories to involve in a overall database of the streetlamps that would be used for maintenance?
- National Grid's perspective on the installation of LED lights
    - What information does National need to know or already have about the streetlamps?
    - Why would National Grid be interested in supporting the conversion of LED lights for the streetlamps?

    - What are the incentives for an LED light efficiency program that can be obtained from National Grid?
    - What are the responsibilities of National Grid vs. Ryder Electrics in terms of streetlamp upkeep?
- Views/Opinion of the use of LED Streetlamps on Nantucket
    - In your opinion, is there adequate lighting in the downtown area?
    - Should Town resources be allocated to improve the conditions and maintenance of the streetlamps?
    - Were you able to identify any of the LED retrofit pilot sites in downtown?
        - Did you have any general observations or initial thoughts on the LED lights?
        - What is your opinion of the brightness and color temperature of the pilot lights you observed?
        - Do you think color temperature and look of the LED lights are appropriate for the historic district?
        - Do you think the public would accept this change to LED lights in the historic downtown area?
    - What type of questions would you feel are appropriate for a survey to the public on the lights?
- Do you have any other people whom you think we should contact for this project?

Elizabeth Gibson (Town Manager)

- Brief background and historical context of streetlamps.
    - What were the past processes on streetlamps?
- Explain the creation of a master inventory database of the streetlamps.
    - Who would be the department/person in the Town that should maintain and keep up to date the database?
- What is the chain of communication for the streetlamp reporting process?
- In regards to the survey, what type of data from the survey would be important to support the goal of receiving more money for streetlamp maintenance?
- Do you have any other people who you think we should contact for this project?

John Smith (DPW)

- General Background Questions
    - What are your responsibilities at the DPW?
    - Timeline of streetlamp maintenance and historical processes
- Decorative Streetlamps
    - Are you familiar with the regulations on the lighting in the downtown area?
    - What are the requirements for the decorative streetlamps that are installed, private or town owned? For example: the music school on 56 Centre St.
    - Are the requirements for the lamp fixtures to be opaque tops and translucent sides a requirement for the type of streetlamps that should be installed?
- Maintenance
    - In your opinion, is there adequate lighting in the downtown area?
    - Should Town resources be allocated to improve the conditions and maintenance of the streetlamps?
    - Is there any kind of regular maintenance plan set up for the decorative streetlamps in the downtown area?
    - Is there a log or method of keeping track of repairs done on the streetlamps?
    - What are common repairs you make on the streetlamps? How long does these repairs normally take?
    - What other categories should we include in the inventory for the maintenance?
- Reporting and Communication
    - When you fix or repair a streetlamp who do you communicate to about the repair? National Grid? A Town Official? Who do you consult with on decisions about the streetlamps?
    - What is the reporting process for the streetlamps? What is the chain of communication?
    - Do you think the current process needs improvement?
    - Who should be responsible for updating the map and conveying the reports?
- LED Pilot Project Questions
    - Were you able to identify any of the LED retrofit pilot sites in downtown?

        - Did you have any general observations or initial thoughts on the LED lights?
        - What is your opinion of the brightness and color temperature of the pilot lights you observed?
        - Do you think color temperature and look of the LED lights are appropriate for the historic district?
        - Do you think the public would accept this change to LED lights in the historic downtown area?
- Final Questions
    - Do you have any final question or requests for clarification on our project?
    - Do you have any other people whom you think we should contact for this project?

Phil Albertson (Ryder Electric)

- General Background
    - How long have you been working for the Town?
    - What are your responsibilities under the contract?
- Maintenance & Inventory
    - Does Ryder currently have a database/inventory on all the decorative streetlamps?
    - What information would you like to know for maintenance?
    - Specifically, is there a record of the maintenance that is performed on each streetlamp?
    - What are the maintenance responsibilities of Ryder Electric in regards to the streetlamps? Does Ryder change light bulbs? Check the wires? Why are Ryder employees in manholes?
    - Why is the fixtures now fixed when on the post instead of having the head removed by National Grid and fixed in the shop?
    - Which method would be best for you to update invoices to the Town?
- Reporting
    - What are your thoughts on the current reporting system for lamp outages?
    - Do you feel there is a more effective way of reporting issues for the public?

    - Do you feel a dedicated streetlamp webpage on the town website would be an easier way to report lamp issues?
- LED Lights
    - What are your past experiences with LED lights?
    - Do you think that the LED lights would impact your repairs on the streetlamps?
    - How would you feel if the Town goes through an LED conversion?

Marcus Silverstein (Lighting Inspector)

- General Background:
    - What is your role as the Lighting Inspector?
- Light Regulations
    - What do you look into when inspecting lights?
    - Are you familiar with foot-candles? Would you be able to explain more about measuring the ambient light?
    - What are some of the code regulations for lighting on Nantucket?
    - Have you come across any problems involving the streetlamps?
    - What are some common concerns that you receive from the public about the streetlamps?
    - What is the criteria for adequate street lighting?
    - Does the current amount of streetlamps supply adequate lighting in the downtown area? If not, who would make the decision to add more lights and where should they be placed?
    - How do you feel about the current lights in the downtown district?
- LED Lights
    - How familiar are you with the LED lights and what's your opinion of them?
    - Display Amerlux LED. Do you feel this light color and brightness is appropriate for the downtown area? Would this LED follow the codes set forth by the town?
    - Have you noticed any of the LED pilot lights installed in the downtown area? Have you received any complaints about them?
    - How would you feel about a full installation of LED Streetlamps in the downtown area?

Dr. Peter Boyce

- General Background Questions
    - What is your academic background and general involvement on the island of Nantucket?
    - From Dr. Oktay, we heard that you did research on the light pollution. Can you tell us more about your research?
- Concerns Regarding Lighting
    - Are there any current concerns with lighting affecting the environment on the island?
    - Regarding the streetlamps in the downtown area do you feel there are any negative impacts?
    - What is your opinion of the current condition of light pollution in the Town?
        - What are your thoughts on the relationship between LED's and light pollution?
- Opinion on Streetlamps (Survey Questions)
    - Do you think the lighting in the downtown area is adequate?
    - What is your opinion on the condition of the streetlamps?
    - Should Town resources be allocated to improve the conditions and regularly maintain the streetlamps?
    - Were you able to identify any of the LED retrofit pilot sites in downtown?
        - Did you have any general observations or initial thoughts on the LED lights?
        - What is your opinion of the brightness and color of the pilot lights you observed?
        - Do you think look of the LED lights are appropriate for the historic district?
        - Do you think the public would accept this change to LED lights in the historic downtown area?
        - Would you be in favor of a conversion of all the decorative streetlamps to LED lights?

- Final Questions
    - Do you have any final question or requests for clarification on our project?
    - Do you have any other people whom you think we should contact for this project?

Leslie Snell (Deputy Director of Planning)

- General Background
    - What is your role as the Deputy Director of Planning?
    - What is your past experience with the decorative streetlamps in the downtown area?
- Street Lighting
    - What are some of the code regulations for lighting on Nantucket?
    - Have you come across any problems involving the streetlamps?
    - What are some common concerns that you receive from the public about the streetlamps?
    - What is the criteria for adequate street lighting?
    - Does the current amount of streetlamps supply adequate lighting in the downtown area? If not, who would make the decision to add more lights and where should they be placed?
    - How do you feel about the current lights in the downtown district?
- LED Lights
    - How familiar are you with the LED lights and what's your opinion of them?
    - Do you feel this light color and brightness is appropriate for the downtown area? Would this LED follow the codes set forth by the town?
    - Have you noticed any of the LED pilot lights installed in the downtown area? Have you received any complaints about them?
    - How would you feel about a full installation of LED Streetlamps in the downtown area?

Kara Buzanoski (DPW)

- General Background
    - What is your major responsibilities at the DPW?

    - What is your experience with the decorative streetlamps?
- Reporting & Inventory
    - What is the current inventory that DPW has on the streetlamps? What has been past streetlamp inventory protocol?
    - What important maintenance information should be included in the database?
    - Who do you think should be responsible for updating and maintaining the master inventory database?
    - What is the current process for reporting light outages and lamp issues?
    - For people who utilize the SeeClickFix Application.
        - What streetlamp problems do you receive through the application?
        - How often do you receive reports through this application?
        - Who receives these reports?
        - Where do the work orders from those forms delegate to?
    - Do you feel a dedicated webpage would be helpful for people to report streetlamp problems?
        - What information would you recommend we include for reporting issues?
        - What would the public want to know?
- LED Opinion
    - How do you feel about the possibility of an LED installation in the streetlamps?

Jason Bridges

- **Show Inventory:** What google accounts should be linked to the inventory system?
    - Who do you think should be in charge of updating the inventory based from your experience?
    - Do you think this system is simple for the officials to update information on?
- **Show Interactive Map:** We are uploading pictures to each streetlamp, is there a permanent place to put the pictures so that they have a stable URL?
    - How would you link a reporting system to the interactive map? SeeClickFix or a reporting form?
- We are also conducting online survey that will be linked to a QR code, are you familiar with the success rate of QR codes being used on Nantucket? Did the public know it?

- As a business owner:
    - Do you think there is adequate lighting in downtown area?
    - Does the current lighting affects your business?
    - Have you noticed the pilot LED lights that have been installed in the downtown area? If so, how do you feel about them?

Chief William Pittman (Nantucket Police Department)

- General Information:
    - Are you involved with overseeing of streetlamps in the downtown area?
        - Have you noticed the conditions of the lights?
        - Do you collect information about their conditions? For example, through night patrols?
- Safety
    - Do you think there is adequate lighting in the town?
    - What are your major concerns involving the amount of lighting in the downtown area from the streetlamps?
    - Have there been prior issues that the police have had to respond to that could have been avoided with more reliable lighting in the downtown area?
- Reporting Issues
    - Do you receive the public's complaints or reporting of the streetlamps?
    - What are some of the common issues you encounter and how often do you receive them?
    - How do people contact you about the lights?
    - Do you need a database of the lights for safety issues if the public question?
        - What information would you need for the database?

Michael May (Preservation Trust)

- What are keys factors that are important to preserve the historic district on Nantucket?
    - What do you think the public views as important features of the historic district?
    - In addition overall, what level of importance do you think the public places on the preservation of the historic district?

- High Pressure Sodium (HPS) bulbs are currently used in the decorative streetlamps in the downtown area.
    - Do you think the current lights are an appropriate color for the historic district?
- Three lighting companies are providing pilot LED retrofits in similar color ranges as the current HPS range.
    - With this factor and the idea that the LEDs would be more reliable, save money, and decreases energy usage, would your organization be in favor of an LED retrofit conversion project?
- Please add any additional information or concerns that you feel would be relevant to our project.

Joe Cardinal (National Grid)

- Do you have experience with the installation of LED lights in other towns, specifically historic districts?
    - What are some of the complications you encountered and feedback from the public?
- Another component of our project is creating a database of the current condition and maintenance of the streetlamps.
    - What is National Grid's current process for reporting maintenance and inventory of the streetlamps?
    - In addition, what is the protocol for communication with the Town of Nantucket on issues with the streetlamps?
- In addition, we are creating a process for the residents of Nantucket to report problems to the Town regarding the streetlamps.
    - Do you have any suggestions on how to improve the reporting process for the public's use?
- What are some of the different tariff rates that contain reduced cost for an LED conversion, specifically the S-5 rate?
    - Can you please expand upon the difference between the S-5 and current S-3B rates, specifically in regards to cost and maintenance responsibilities of National Grid.

    - What type of information is required to be able to calculate the estimated S-5 rate for our economic analysis?
- Please explain why National Grid would be interested in supporting the conversion of the HPS lights to LED for the streetlamps in Nantucket.

Michelle Stonier (PennGlobe)

- We have read the case studies on the PennGlobe website. Does PennGlobe have additional experience with implementing LED retrofits in other towns, specifically historic districts?
    - If so, would you be able to send us further information on these cases that are not on the website. In particular, have you received any public feedback on the LED retrofits you have installed in the past?
- In regards to your company's LED retrofits, do you see any possible concerns with the retrofit for Nantucket's streetlamps?
    - For installation, what is generally the average time for a retrofit?
- What are the components of maintenance of your LED retrofits?
    - For example, if a complication occurred with the LED lights, how would the problem be troubleshoot?
- What is the expected warranty of your LED retrofit kits? In particular, are there any economic upsides to your retrofit installations compared to another company?
- Do you feel that your LED retrofits would fit the historic aesthetics and atmosphere of the Town of Nantucket?

Scott Thompson (Amerlux)

- Does Amerlux have additional experience with implementing LED retrofits in other towns, specifically historic districts?
    - If so, would you be able to send us further information on these cases. In particular, have you received any public feedback on the LED retrofits you have installed in the past?
- In regards to your company's LED retrofits, do you see any possible concerns with the retrofit for Nantucket's streetlamps?
    - For installation, what is generally the average time for a retrofit?

- What are the components of maintenance of your LED retrofits?
    - For example, if a complication occurred with the LED lights, how would the problem be troubleshooted?
- What is the expected warranty of your LED retrofit kits? In particular, are there any economic upsides to your retrofit installations compared to another company?
- Do you feel that your LED retrofits would fit the historic aesthetics and atmosphere of the Town of Nantucket?

Lana Nathe (Lighting Consultant)

- Do you have any experience with LED lights?
- On average, what is the duration of the installation for LED lights?
- What are the components of maintenance of the LED retrofits? For example, if a complication occurred with the LED lights, how would the problem be troubleshooted?
- Many LED companies claim that the lights will last for 20+ years (or roughly 50,000 hours). How credible is this claim?
- Most of LED positive aspects are emphasized but are there a negative side to them also?
- With all the pros and cons, would you recommend a full installation of LED lights throughout a town?
    - Do you feel that your LED retrofits would fit the historic aesthetics and atmosphere of the Town of Nantucket?
- Where do you think the future of LED technology will go?

Business Owners

- Do you think there is adequate lighting in downtown area, specifically outside your business?
- Does the current lighting affect your business? In other terms, is the light welcoming for your business entrance?
- Have you noticed the pilot LED lights that have been installed in the downtown area? If so, how do you feel about them?
    - Have you heard any complaints about the lights?
    - How do the customers feel about the lights?

- Do you think brighter or different color lights will attract more customers to your business?

Appendix B: FormConnect Pro Form

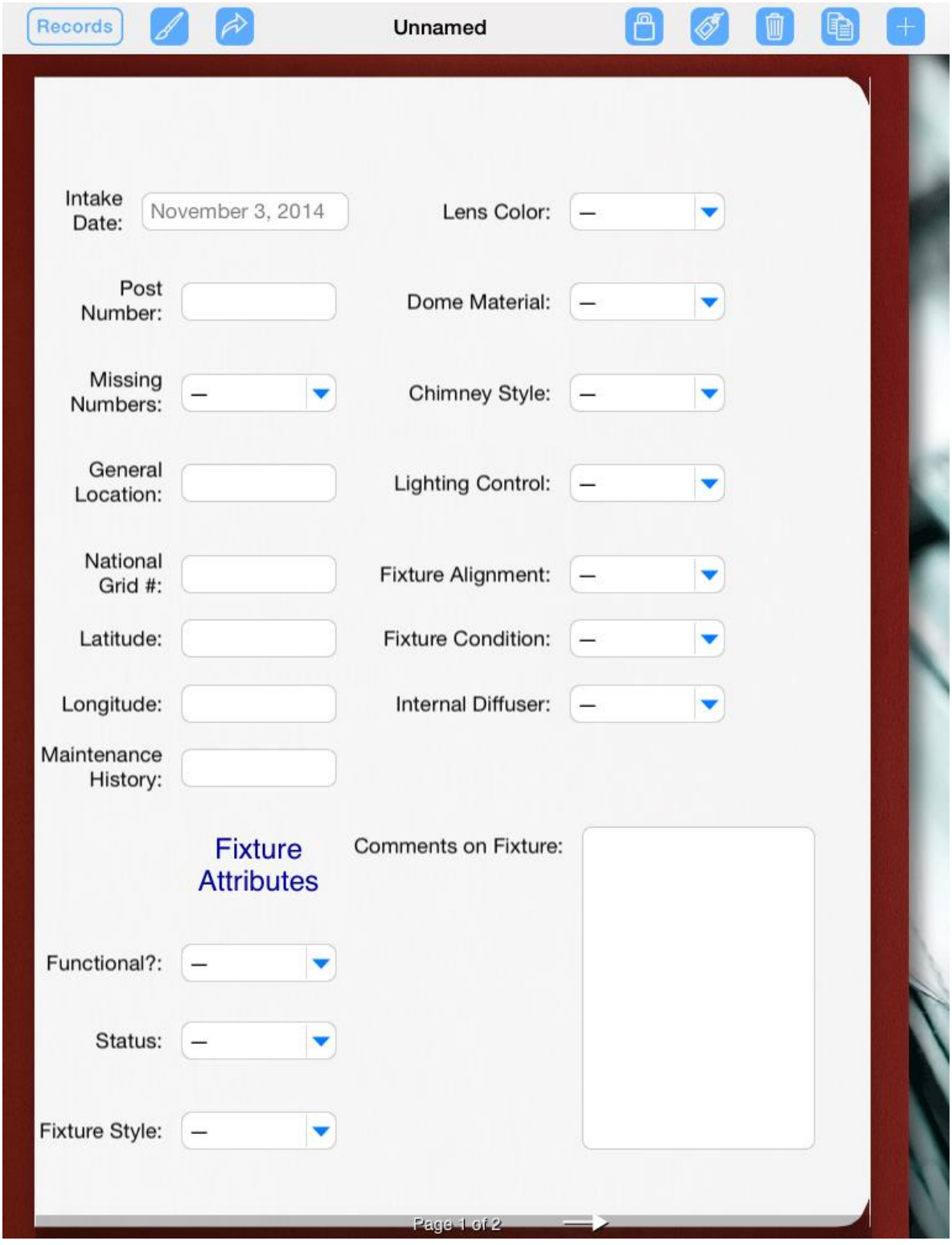

Figure 44 FormConnect Pro Page 1

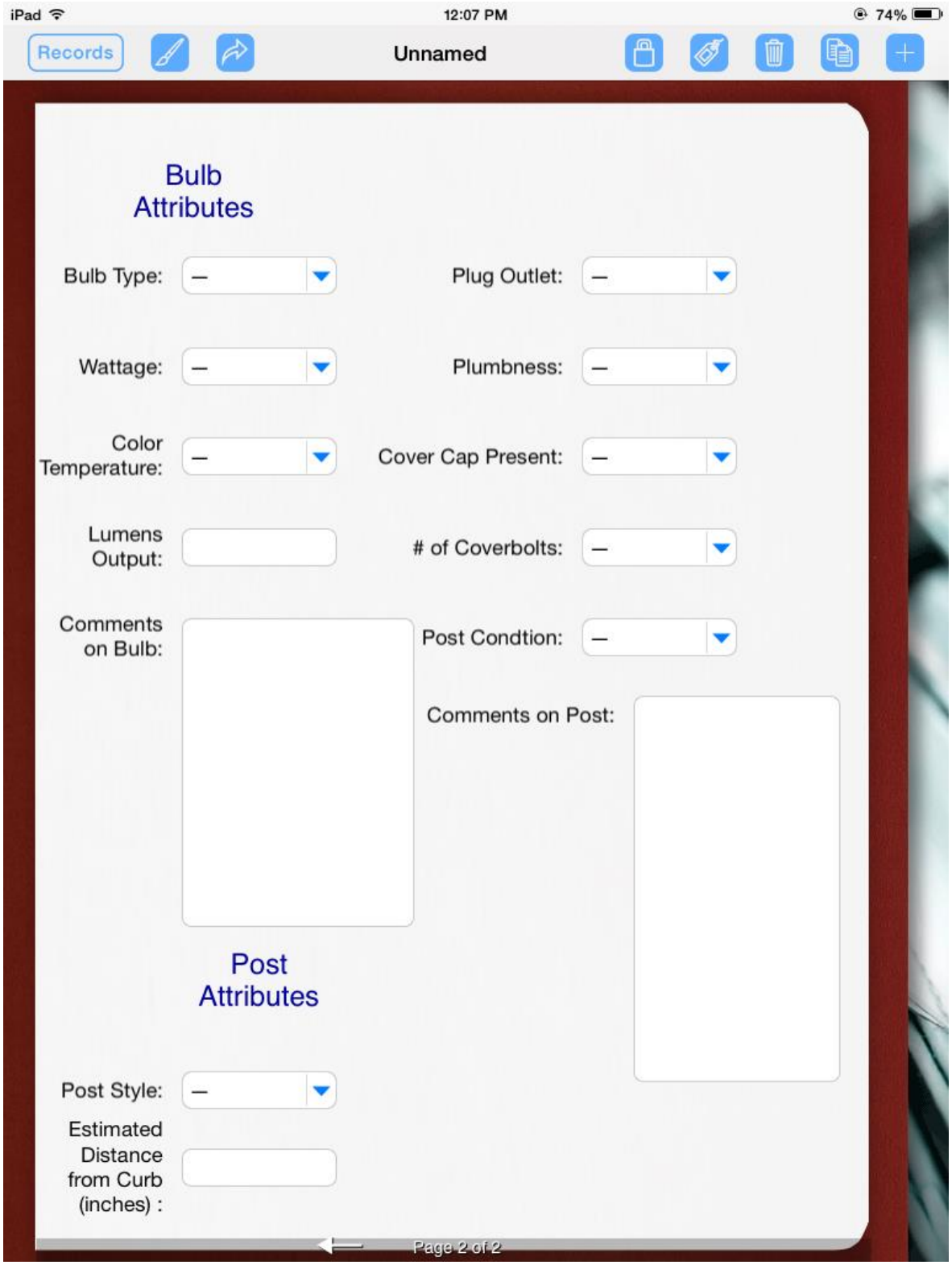

Figure 45 FormConnect Pro Page 2

Appendix C: Surveys

TO BE COMPLETED BY SURVEYOR:
Survey #:____ M/F Date: _____ Time: _____ Weather: _____ Location: _____ Initials: ____

Town of Nantucket Streetlamp Survey

1. Residency Status: ☐ Full-time Resident ☐ Seasonal Resident ☐ Visitor
2. Age Group: ☐18-25 ☐ 26-35 ☐36-45 ☐46-55 ☐56-65 ☐ > 65
3. Do you live in the downtown area? ☐ Yes ☐ No
4. Do you work in downtown area? ☐ Yes ☐ No
5. Do you think the amount of lighting in downtown is adequate? ☐ Yes ☐ No ☐ Unsure
6. Please indicate your level of satisfaction with the condition of the streetlamps throughout the downtown area. ☐ Dissatisfied ☐ Satisfied ☐ Unsure
7. Should additional Town resources be allocated to improve the conditions and regularly maintain the streetlamps? ☐ Yes ☐ No ☐ Unsure
8. Would it be helpful to the public if the Town maintained a streetlamp webpage with an interactive map for reporting outages and viewing repair statuses?
   ☐ Yes ☐ No ☐ Unsure
9. Pilot LED lights have been installed in select streetlamps in the downtown area. Have you noticed any of the LED lights? ☐ Yes ☐ No

Please at this point ask the surveyor to identify the LED light at this location.

10. Do you think this LED is appropriate for the downtown area? ☐ Yes ☐ No ☐ Unsure
11. Please indicate your opinion of the following LED characteristics.

	Strongly Dislike				Strongly Like
a. Brightness	1	2	3	4	5
b. Color	1	2	3	4	5
c. General Visibility	1	2	3	4	5
d. Overall	1	2	3	4	5

12. Which streetlight color do you prefer? ☐ Current Lighting (HPS) ☐ LED
13. Which streetlight brightness do you prefer? ☐ Current Lighting (HPS) ☐ LED
14. Would you be in support of an LED conversion project if the Town was able to reduce electricity usage and save on costs associated with frequent maintenance and repairs?
    ☐ Yes ☐ No

Thank you for participating in the survey!

Figure 46 Handout Survey

Town of Nantucket Streetlamp Survey - Location 1

This is a collaborative research project between the Town of Nantucket Energy Office and Worcester Polytechnic Institute to determine the social and economic feasibility of retrofitting the Town's nearly 200 decorative streetlamps to LEDs. The purpose of this survey is to gauge public acceptance and attitudes towards the current streetlight conditions and the LED retrofit pilots.

Please indicate your opinion of the following LED characteristics for THIS location.

1 = Strongly Dislike to 5 = Strongly Like

	1	2	3	4	5
Brightness	○	○	○	○	○
Color	○	○	○	○	○
General Visibility	○	○	○	○	○
Overall	○	○	○	○	○

Do you think this location's LED is appropriate for the downtown area?

- ○ Yes
- ○ No
- ○ Unsure

Would you support a LED conversion project if the Town was able to reduce electricity usage and save on costs associated with frequent maintenance and repairs?

- ○ Yes
- ○ No
- ○ Other:

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Figure 47 QR Survey Page 1

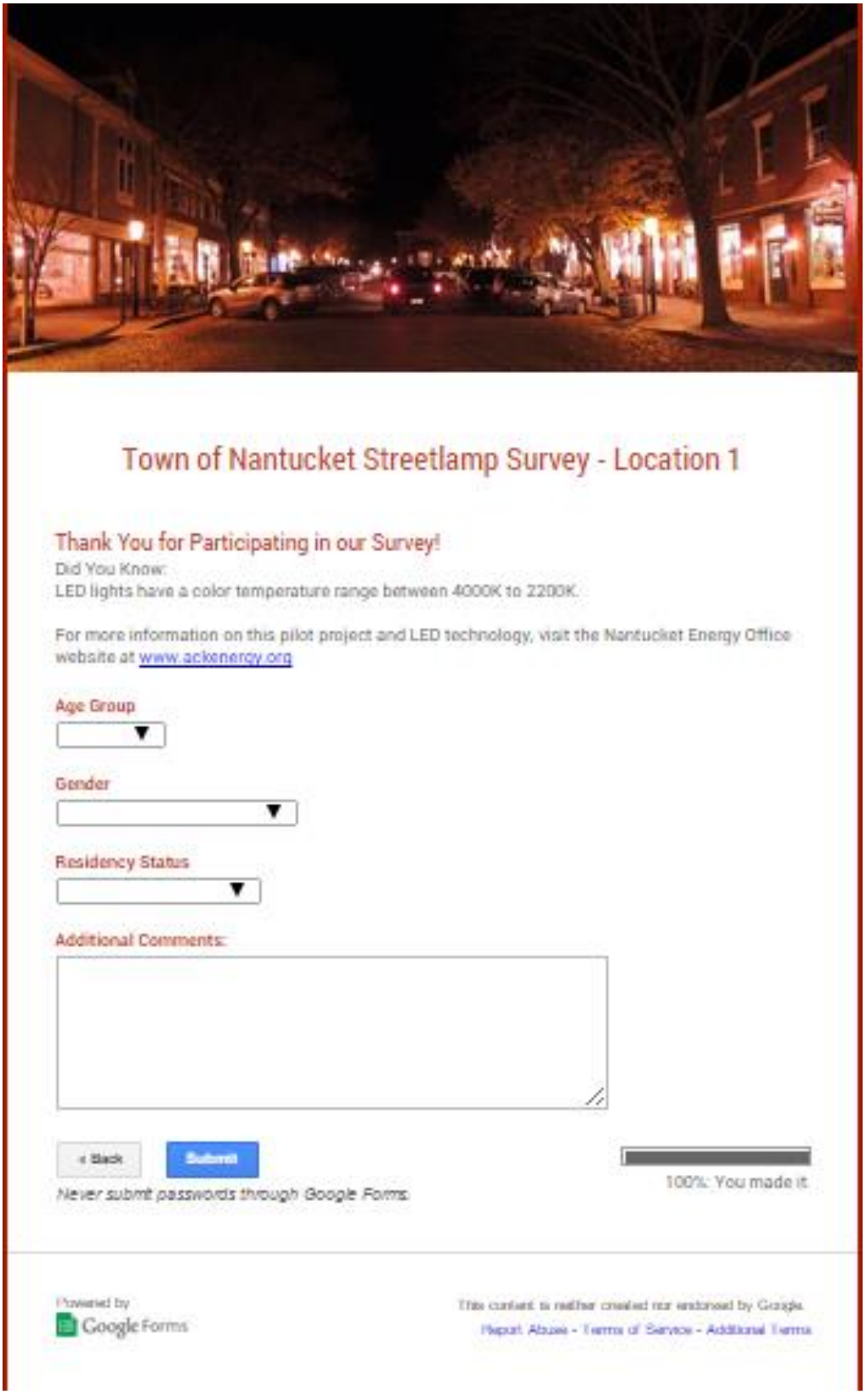

Figure 48 QR Survey Page 2

Town of Nantucket Streetlamp Survey

This is a collaborative research project between the Town of Nantucket Energy Office and Worcester Polytechnic Institute to determine the social and economic feasibility of retrofitting the Town's nearly 200 decorative streetlamps to LEDs. The purpose of this survey is to gauge public acceptance and attitudes towards the current streetlight conditions and the LED retrofit pilots.

Do you think the amount of light in the downtown area is adequate?

- Yes
- No
- Unsure

Please indicate your level of satisfaction with the condition of the streetlamps throughout the downtown area.

- Dissatisfied
- Satisfied
- Unsure

Should additional Town resources be allocated to improve the conditions and maintenance of the streetlamps?

- Yes
- No
- Unsure

Would it be helpful to the public if the Town maintained a streetlamp webpage with an interactive map for reporting outages and viewing repair statuses?

- Yes
- No
- Unsure

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Figure 49 Online Survey Page 1

Town of Nantucket Streetlamp Survey

LED Retrofit Pilot Questions

9 LED retrofits have been installed in different decorative streetlamps for this pilot project. The LED pilot locations are identified by signs on the lamp posts. Each sign has a QR code linked to a survey for public feedback.

Prior to taking this survey, have you noticed any of the LED lights?

- Yes
- No

Please indicate the importance you would place on the following reasons for replacing the existing HPS streetlights with LED lights (1 = Not Important to 3 = Very Important)

	1	2	3
Increased Reliability			
Uniformity Between Various Streetlamps			
Decreased Energy Usage			
Reduced Maintenance Costs			
Reduced Operating Costs			
Increased Public Safety			
Reduced Negative Environmental Impacts			

Would you support a LED conversion project if the Town was able to reduce electricity usage and save on costs associated with frequent maintenance and repairs?

- Yes
- No

Why/why not?

Figure 50 Online Survey Page 2

Town of Nantucket Streetlamp Survey

Thank You for Participating in our Survey!

For more information regarding this project and LED technology please visit the Nantucket Energy Office website at www.ackenergy.org

Age Group

Gender

Residency Status

Do you live in the downtown area?

- Yes
- No

Do you work in the downtown area?

- Yes
- No

Additional Comments:

« Back Submit

100%: You made it.

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Figure 51 Online Survey Page 3

Appendix D: National Grid Tariff Rate

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Smart Growth & Regional Collaboration

National Grid Streetlight Tariff S-5 Summary for LED Retrofits

Overview

The National Grid "Street and Area Lighting – Customer Owned Equipment S-5 Retail Delivery Service" tariff is available to any municipality that owns their street lights in National Grid's jurisdiction. This guide is designed to help municipalities who own street lights that receive retail delivery service from National Grid to understand the tariff and to calculate potential energy and energy cost savings from LED streetlight conversions. To estimate energy savings (or costs under this rate) a municipality will need to have an accurate count of street and area lighting fixtures, existing wattage information for each fixture, and the corresponding LED wattage for each. This may require the expertise of a lighting consultant and full review of the National Grid Rates Tariff.

Applicability

This tariff is available to any municipal city or town that purchases designated National Grid street and area lighting equipment pursuant to G.L. c. 164 § 34A and is receiving delivery service. These "Municipal Customers" include:

- Customers currently on Rate S-1, S-3 Option A, S-6, or S-20 that purchase street and area lights, and dedicated poles, standards or accessories.
- Customers that already purchased street and area lighting equipment under Rate S-2, Street Lighting – Overhead – Customer Owned Equipment or Rate S-3 Option B, Street Lighting – Underground – Division of Ownership.

This tariff is also open to any municipal city or town, governmental entity, or other public authority ("Customer") wishing to make additions of customer-owned luminaires that were not specifically purchased pursuant to G.L. c. 164 § 34A (M.D.P.U No. 1217, Sheet 1).

For Municipal Customers moving to Rate S-5 from Rate S-1, S-3 Option A, S-6 or S-20, items that need to be completed prior to receiving service under this tariff include:

- Compliance with all provisions and terms of the former tariff.

- Execution of a written purchase and sale agreement for National Grid's designated street and area lighting equipment, and dedicated poles, standards or accessories.
- Completed transfer of title to the equipment from National Grid to the customer.
- Execution of a license agreement between the customer and National Grid.
- Written notice to National Grid of any replacements of or additions to customer-owned street and area lighting equipment.

For Municipal Customers moving to Rate S-5 from Rate S-2 or S-3 Option B, items that need to be completed prior to receiving service under this tariff include:

- Compliance with all provisions and terms of the former tariff, including the completion of all planned conversions from Company-owned to customer-owned equipment under the former tariff.
- The execution of a separate service agreement and license agreement between the customer and National Grid.
- Written notice to National Grid of any replacements of or additions to customer-owned street and area lighting equipment.

For Customers who are not specifically Municipal Customers, receiving service under this tariff is contingent upon written notice to National Grid of the addition of customer-owned luminaires as well as the execution of a service agreement between the Customer and National Grid.

Cost items that this tariff does not include are:

- Maintenance of street and area lighting equipment owned by the customer (absent a separate contract with National Grid).
- LED retrofit conversion costs, including survey, purchase, and installation costs.
- Potential associated fees.
- Potential Mass Save® energy efficiency incentives.[1]

[1] National Grid uses rated wattage to calculate incentives. For non-LED lamps, rated wattage includes the power drawn by the lamp and the ballast (e.g., a 50 Watt high pressure sodium light has a rated wattage of 65 Watts because of the power consumed by the ballast). For LED lamps, the rated wattage is just the nominal wattage (a 10 Watt LED has a rated wattage of 10). For more information on rated wattage, please see: http://www.masssave.com/~/media/Files/Professional/Applications-and-Rebate-Forms/2013-Applications/Device-Codes-and-Rated-Lighting-System-Wattage-Table-Retrofit.pdf

Calculate Energy Use & Savings

The following is a guide to estimate your energy cost and use for your streetlight portfolio. This calculation does not estimate the survey, purchase, installation, and maintenance costs or potential Mass Save® incentives for the LED fixtures.

Steps To Calculate Energy Savings from Converting to LEDs

Step 1: Create a street and area lighting inventory. Contact National Grid for your billing inventory and compare the inventory list to actual number of fixtures you have. Alternatively, you can create your own streetlight inventory. At minimum, you need to know the quantity, type, and wattage of each existing light.

Step 2: Determine the wattage of the probable replacement LED fixture for each existing fixture. To determine potential LED replacement fixtures, see Table 3 or work with a street lighting consultant.

Step 3: Identify energy usage and costs for the existing streetlight portfolio and estimate energy used and costs of the new portfolio.

Identify Energy Use and Cost for Existing Fixtures

1. To identify the energy use and costs for existing street and area lighting, you can either look at past records, including bills or MassEnergyInsight, or you can use the annual usage levels and costs identified in National Grid's tariff. See Table 2 for a summary of usage levels and costs from the tariff.

2. Calculate Total Existing Annual Cost: Sum all Total Annual Cost per Fixture Types

Calculate Estimated Energy Use and Cost for LED Retrofits

3. Determine Billable wattage for each of the LED fixtures that you have selected to replace your existing streetlight fixtures.

Table 1: LED Street Light Annual Billable Usage

Nominal Wattage Range*		Billable Wattage	Annual kWh
Lower	Upper		
0.1	50	25	104
50.1	100	75	313
100.1	150	125	522
150.1	200	175	731
200.1	250	225	939
250.1	300	275	1148

* LED Nominal Wattage is inclusive of the total device wattage (LED, driver, and control).

Source: M.D.P.U. No. 1217: Massachusetts Electric Company, Street and Area Lighting
- Customer Owned Equipment S-5, Retail Delivery Service tariff
http://www.nationalgridus.com/masselectric/non_html/rates_tariff.pdf.

4. Calculate LED fixture energy charges: (LED Billable Wattage x 4,175 Hours of Operation) ÷ 1000 = Total kWh. (Or reference Table 1: LED Street Light Annual Rated Usage (below) to look up Annual kWh)

> Example: A municipality will replace HPS 58-watt lamps with LED 28 watt lamps: (25 x 4175) ÷ 1000 = 104
>
> *25 is the Billable Wattage which is used instead of the Nominal Wattage under this tariff. For each range of Nominal Wattages (shown in Table 1) a Billable Wattage value has been assigned*

5. Calculate Total Annual Electricity Cost Per LED Fixture Type: (Total kWh x Current Retail Delivery and Supply Rate[2] x Quantity of Fixtures = Total Cost per Fixture Type)

6. Calculate Total Annual Energy Cost: Sum all Total Cost per Fixture Types

7. Calculate Estimated Total Annual Energy Savings: Total Existing Cost – Total LED Cost

Calculate Incentives

National Grid uses rated wattage to calculate incentives. For non-LED lamps, rated wattage includes the power drawn by the lamp and the ballast (e.g., a 50 Watt high pressure sodium light has a rated wattage of 65 Watts because of the power consumed by the ballast). For LED lamps, the rated wattage is just the nominal wattage (a 10 Watt LED has a rated wattage of 10). For more information on rated wattage, please see: http://www.masssave.com/~/media/Files/Professional/Applications-and-Rebate-Forms/2013-Applications/Device-Codes-and-Rated-Lighting-System-Wattage-Table-Retrofit.pdf

[2] The current retail delivery rate for LED streetlights under the S-5 tariff is $0.06207 per kWh, however National Grid's retail delivery rate for LED streetlights will change periodically. National Grid therefore, advises customers to review the Company's most recent summary of electric delivery service rates tariff to identify the current rate. The retail delivery rate does not include the cost of supply service.

Appendix 1: Reference Tables

The following information is provide for reference only, and should not be a substitute for a thorough analysis of the tariff or the municipality's lighting system. The historic LED replacement information provided is based upon completed projects in Massachusetts and should not be used in place of a project-specific design created by a lighting professional.

Table 2: Non-LED Fixture Total Energy Use

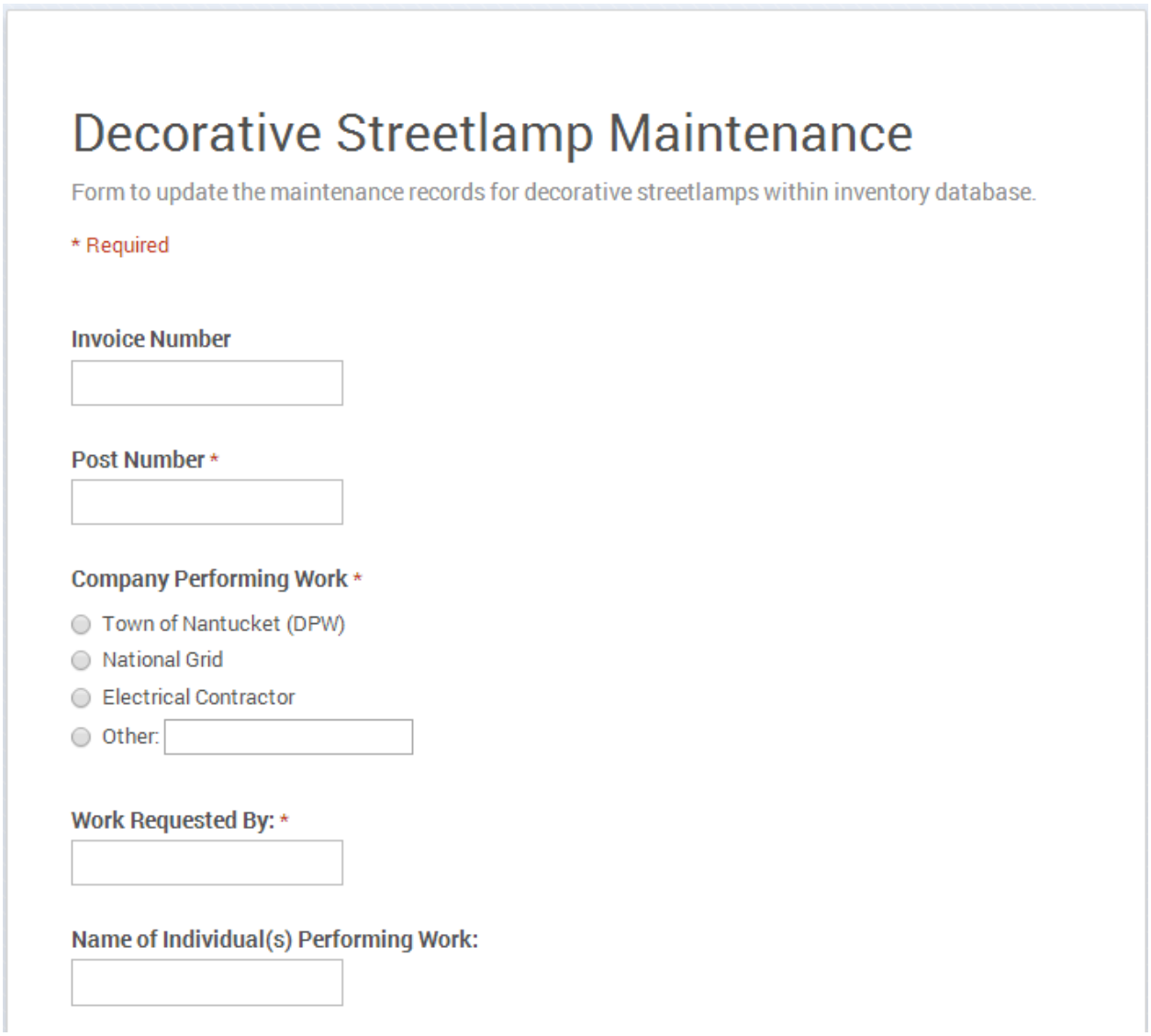
Luminaire Type	Lumen Rating	Nominal Wattage	Annual kWh
Incandescent			
Roadway	1000	105	438
Roadway	2500	205	856
Mercury Vapor			
Post Top	4400	100	543
Post Top	8500	175	881
Roadway	4400	100	543
Roadway	8500	175	881
Roadway	13000	250	1282
Roadway	23000	400	1991
Roadway	63000	1000	4572
Floodlight	23000	400	1991
Floodlight	63000	1000	4572
High Pressure Sodium Vapor			
Post Top	4000	50	255
Post Top	6300	100	359
Roadway	4000	50	255
Roadway	6300	70	359
Roadway	9600	100	493
Roadway	16000	150	722
Roadway	27500	250	1269
Roadway	50000	400	1962
Roadway	140000	1000	4618
Floodlight	27500	250	1269
Floodlight	50000	400	1962
Wallighter (12 Hr.)	27500	250	1332
Wallighter (24 Hr.)	27500	250	2663
Metal Halide			
Floodlight	32000	400	1883

Table 3: Historic LED Replacement Information

Existing Fixture Type & Nominal Wattage	LED Wattage Range
Incandescent 90W	15-30
Mercury Vapor 100W	20-35
Mercury Vapor 175W	34-108
Mercury Vapor 250W	45-108
Mercury Vapor 400W	56-154
High Pressure Sodium 35W	20-25
High Pressure Sodium 50W	25-30
High Pressure Sodium 100W	34-45
High Pressure Sodium 150W	56-108
High Pressure Sodium 250W	74-108
High Pressure Sodium 400W	97-168

Source: Metropolitan Area Planning Council, *RFQ Streetlight EMS 2 and RFQ responses,* July 10, 2013 & August 16, 2013.

Appendix E: Maintenance Form



Decorative Streetlamp Maintenance

Form to update the maintenance records for decorative streetlamps within inventory database.

* Required

Invoice Number

Post Number *

Company Performing Work *

- Town of Nantucket (DPW)
- National Grid
- Electrical Contractor
- Other:

Work Requested By: *

Name of Individual(s) Performing Work:

Figure 52 Decorative Maintenance Form Part 1

General Maintenance Performed *

Check All That Apply

- [ ] Installed New Light Bulb
- [ ] Installed Photocell
- [ ] Installed New Ballast
- [ ] Installed New Fuse
- [ ] Checked Electricity Supplied to Streetlamp
- [ ] Replaced Fixture
- [ ] Replaced Post
- [ ] Reworked Fixture
- [ ] Installed LED Retrofits
- [ ] Replaced Coverplate
- [ ] Addressed Exposed Wires
- [ ] Paint the Post
- [ ] Paint the Fixture
- [ ] Other:

Description of Work Performed: *

Figure 53 Decorative Maintenance Form Part 2

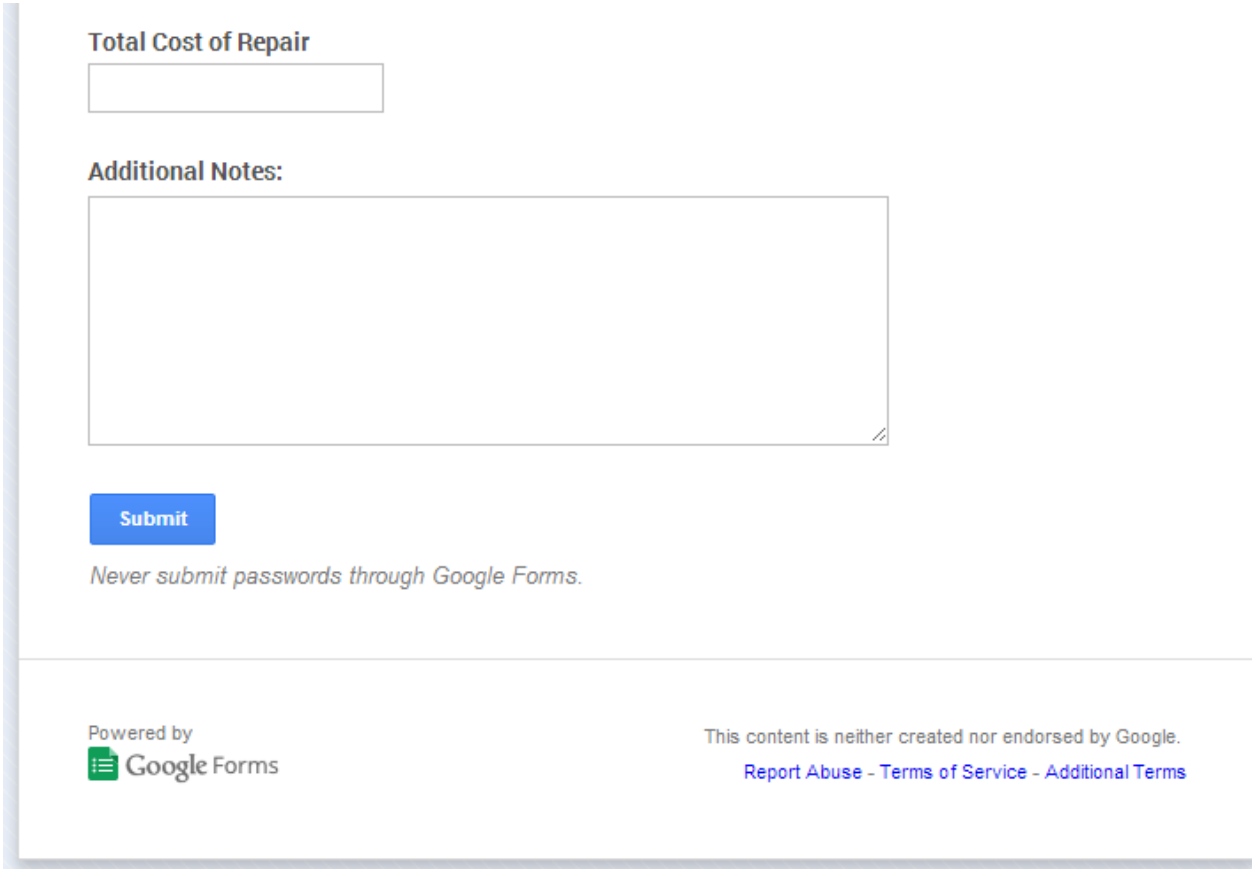


Figure 54 Decorative Maintenance Form Part 3

Appendix F: Inventory Manual

Streetlamp Inventory Instructional Guide

Table of Contents

Chapter 1: Updating Inventory File

This is instructions on how to update the master file when an issue is reported on a streetlamp through the online reporting form from either the public or the DPW. The user in charge of the file would update the appropriate columns for the specific streetlamp identified for the issue identified on the form. The flowchart below identifies at what point in the process the inventory database should be updated and the type of update.

Updating “Status” Column

To change the “Status” column of the general information sheet of the file, use the dropdown menu to choose the current status of the streetlamp.

No Issues at Present :

This is the default status of the streetlamp for when there are no current issues that need to be addressed. This is the status that the user should update when a repair is completed.

Issue Has Been Reported:

This status is chosen when a reporting form is submitted. This status indicates that the issue has been identified.

Issue is Being Addressed:

The status is updated to this option when the work order has been created to address the issue and the responsible group is working on the streetlamp.

Remove from Inventory:

This status is present when the streetlamp is no longer present and should not be billed for electricity.

Steps for Updating the File

In the process of repairing the streetlamp, there are three times at which the inventory should be updated by the user. The below steps outline the order of the changes and what information should be changed during each update.

Update 1: Issue Has Been Reported

1. Change the "Status" (Column C) to **Issue Has Been Reported**
2. Change the additional appropriate columns to reflect the issue that was reported:
    a. Issues with Lightbulb - Change "Functional" (Column E) to **No: Stays Dark**, **No: Stays Lit**, or **No: Cycling Issues**
    b. Missing Fixture - Change "Functional" (Column E) to **No: Fixture Missing** and "Fixture Style" (Column K) to **Fixture Missing**
    c. Missing Post - Change "Post Style" (Column Y) to **Post Missing**
    d. Missing Cover Plate - Change "Cover Cap Present" (Column AB) to **No: Needs Attention**
    e. Missing Post Numbers - Change "Missing Number" (Column I) to **Yes**
    f. Issues with Condition of Post
        i. Change "Post Condition" (Column Z) to **Needs Attention** if issue about the physical condition of the pole.
        ii. Change "Plumbness" (Column AA) to **Needs Attention** if issue about the alignment of the post.
    g. Issues with Condition of Fixture
        i. Change "Fixture Condition" (Column R) to **Needs Attention** if issue about the physical condition of the fixture.
        ii. Change "Fixture Alignment" (Column Q) to **Needs Attention** if issue about the alignment of the fixture on the post.
    h. Other - Only change "Status" (Column C) and add additional comments as needed.
3. Update "Date Last Edited" (Column A).

Update 2: Issue is Being Addressed

4. Change the "Status" (Column C) to **Issue is Being Addressed**
5. Update "Date Last Edited" (Column A).

Update 3: Issue Resolved

6. Change the "Status" (Column C) to **No Issue At Present**

7. Change the columns in the data that were previously changed when the issue was reported in **Update 1**.
8. Update “Date Last Edited” (Column A).
9. Complete the **Decorative Maintenance Form.** The link is found in the “Manual For Categories” sheet of the spreadsheet. (https://docs.google.com/forms/d/1BZIFQ8EojO4YP4pgnNuGB31YpjZMi6a6Lr2v8PxYktc/viewform)

   The **Decorative Maintenance Form** is used to keep a record of the maintenance performed on the streetlamp within the inventory database. This is to be completed with the information received on an invoice or email received from the company that performed the work.

Steps for Updating the File When Streetlamp Removed

If a streetlamp is uninstalled, then the inventory database is updated to indicate that the post has been removed and that electricity should no longer be billed for that streetlamp. Updating the database with **Remove from Inventory** rather than deleting the streetlamp completely from the records is to keep track of past streetlamps.

1. Change the “Status” (Column C) to **Remove from Inventory**
2. Change “Post Style” (Column Y) to **Post Missing** to identify there is no longer a streetlamp.
3. Update “Date Last Edited” (Column A).
4. Update the interactive map according to the other manual and contact National Grid to remove the streetlamp from billing.

Chapter 2: Inventory Categories

Date Last Edited	Updated with the date that the fields in the *General Information* sheet was last changed/edited
Post Number	
Status:	
No Issues At Present	No issues with the streetlamp or issues with the streetlamp has been resolved
Issue Has Been Reported	An issue with the streetlamp has been identified and reported to the correct individual
Issue is Being Addressed	The issue is being fixed by the appropriate individual
Remove from Inventory	This streetlamp is no longer in existence and should be removed from billing.
Initial Input Date	The initial date the information on the streetlamps were collected
Functional:	
Yes	The streetlamp turns on at night and works correctly
No: Cycling Issues	The streetlamp cycles on and off
No: Stays Dark	The streetlamp does not turn on
No: Stays Lit	The streetlamp is always turned on
No: Fixture Missing	The streetlamp is not functioning because fixture is missing
-	No information on this category because fixture missing
General Location	The closest street or street address to the streetlamp
Latitude and Longitude	Estimated satellite coordinates of streetlamp location
Missing Number:	
Yes	Only partial number or no number on the streetlamp post
No	Streetlamp number present on the post

-	No information on this category because fixture missing
National Grid Number	National Grid line number for that streetlamp
Fixture Style:	
Philadelphia	Rectangular designed fixture
Boulevard	Cylindrical designed fixture
Fixture Missing	No information on this category because fixture missing
-	No information on this category because fixture missing
Lense Color:	This is the condition of the glass of the fixture
Yellowed	Glass discolored due to ultraviolet rays
Translucent	Glass not clear to control light trespass
Clear	Glass is clear
-	No information on this category because fixture missing
Dome Material:	
Acrylic (Translucent)	Acrylic dome that allows light to release from the top of fixture that is an option for the Boulevard fixture style
Aluminum	Dome material is made of aluminum and is an option for both fixture styles
Copper	Dome material is made of copper and is an option for the Philadelphia fixture style
-	No information on this category because fixture missing
Chimney Style:	
Acrylic Candles	Three clear “candles”
Gas Lamp	Metal pole with two hanging wicks
Powdered Glass	Curved glass chimney with powdered layer on outside
No Chimney	No chimney present in the fixture
Other	Different type of chimney in fixture not listed above
-	No information on this category because fixture missing

Light Control:	
Photocell	Streetlamp turns on according to the photocell located at the top of the streetlamp fixture
Timer	Streetlamp turns on according to a certain predetermined time
None	No light control is identified or photocell is missing
-	No information on this category because fixture missing
Internal Diffuser:	Semi-clear plastic material placed over the light in the fixture to lessen the brightness of the bulb
Yes	Diffuser present in the fixture
No	No diffuser present in the fixture
Fixture Alignment:	Vertical alignment of fixture in relation to the post
Good	Nearly straight
Fair	Slightly misaligned
Poor	Noticeably not aligned with the post
Needs Attention	At risk of detaching from the pole
-	No information on this category because fixture missing
Fixture Condition	Physical conditions of fixture disregarding the fixture alignment
Good	Almost new looking
Fair	Weathered but still looks presentable
Poor	Extremely weathered and could be improved
Needs Attention	Parts of fixture are broken or potentially dangerous
-	No information on this category because fixture missing
Bulb Type:	
HPS	High Pressure Sodium
LED	Light Emitting Diode
Wattage	

100W	
70W	
50W	
<50W (LED)	
Color Temperature:	Color temperature describes the variation of the light color
<3000K	
3000K	
4000K	
>4000K	
-	No information on this category because fixture missing
Plug Outlet:	Outlet at the top of the fixture
Yes	Plug outlet present
No	No plug outlet
Post Style:	
Cast Metal	Made of metal
Wood	Made of wood
Fiberglass	Made of fiberglass plastic material
None/Wall Mounted	Streetlamp does not require a post (i.e. wall mounted)
Post Missing	The streetlamp post is missing, hole in the ground where post should be
Post Condition:	Physical condition of the post disregarding alignment
Good	Almost new looking
Fair	Weathered but still looks presentable
Poor	Extremely weathered and could be improved
Needs Attention	Parts of post is extremely rusted or potentially dangerous
N/A	No information on this category because post missing

Plumbness:	Alignment (angle) of the streetlamp post compared to the street
Good	Nearly 90 degrees
Fair	Slightly tilted
Poor	Noticeably tilted but > 60 degrees
Needs Attention	Post plumbness < 60 degrees
N/A	No information on this category because post missing
Cover Plate Present:	
Yes	Cover plate is not missing
No: Other Type of Material	Cover plate is missing but another type of material is in its place covering the hole
No: Needs Attention	Cover plate is missing with wired exposed
N/A	Post style does not have a cover plate (i.e. Wood, Wall Mounted, etc.)
Number of Coverbolts:	The number of bolts that are present attaching the cover plate to the post Cast Metal post style require 2 bolts to secure their cover plates Fiberglass post style require 3 bolts to secure their cover plates
N/A	Post style does not require a cover plate
0	No bolts are present or the cover plate is missing completely
1	Only 1 bolt present
2	Only 2 bolts present
3	Only 3 bolts present
Estimated Distance from Curb	Approximate distance streetlamp is from the curb measured in inches

Chapter 3: Modifying Database

Adding new Inventory Categories

1. Determine the location of the new inventory category to be implemented.

2. Click on the letter of the column you wish to insert a new column next to and click on the arrow which appears to the right of that letter.
3. Select **Insert 1 Left** or **Insert 1 Right** based on where you want the new column to be located.
4. Once the new column appears, type the category name in the first box and click **Fill Color** in the top tool bar to match the existing categories.
5. To create dropdown menus, select **Data** in the upper toolbar menu and select **Validation**
6. For **Cell Range**, click on  icon and highlight the area in the spreadsheet you wish to create the dropdown menus for. Click **OK**
7. For **Criteria,** select the **List of Items** option and enter each option in the textbox separated by a comma. Do Not Insert a Space Between Commas
8. For **On Invalid Data** section, check the circle for **Reject Input**
9. For **Appearance,** check the **Show Help** option and type out each of the choices with the exact spelling used in the above box. This will be the hint displayed to the user to show all acceptable answers
10. Select **Save** and the dropdown menus will be installed

If any steps were unclear, please view the "Creating Dropdown Menu Choices" section in Chapter 4 in order to understand "Data Validation" further.

Chapter 4: Important Commands for Database

Publishing a Specific Spreadsheet to the web

Publishing a document to the web allows that document to be opened from a given URL. That document can then be viewed without the need to use a login.

To publish any of your files, just follow these steps:

1. Open a document, spreadsheet, presentation, or drawing.
2. Click the **File** menu.
3. Select **Publish to the Web**.
4. While the entire file will be published by default, some file types have additional publishing options available in a dropdown menu:
    - **Spreadsheet**: Choose to publish the entire spreadsheet or individual sheets

5. Click **Publish**.
6. Copy the link that appears and send it to anyone who you'd like to see the file.

Your file will be available for anyone to view from this URL until you either delete your file or choose to stop publishing. If you forget the URL of the document you can just re-enter the document publishing tool to retrieve it.

It's not possible to publish other file types, for example PDFs, from Google Drive at this time.

Note that only one URL can be published per document at this time.

To Stop Publishing Data

1. Open the file.
2. Go to the **File** menu.
3. Select **Publish to the Web**.
4. Under the "Published content & settings" section, click **Stop publishing**.

If you choose to stop publishing, anyone clicking the link to the published file will no longer be able to view it.

Creating a Pivot Table

The use of a pivot table is to display a quick summary of specific data within a spreadsheet. Filters can be applied to only show certain data values as well

To create a pivot table report from data in your spreadsheet, follow these steps:

1. Open the spreadsheet that contains the data you would like to use for your pivot table. If you don't have a data set to use, you can practice using the data in the pivot table report template and instructions in the "Creating a Sample Pivot Table Report" section of the Google Help guide.
2. From the **Data** menu, select **Pivot table report**.
3. A new sheet named "Pivot Table 1" opens in your spreadsheet with the Report Editor open to the right. This sheet contains an empty pivot table report.
4. In the Report Editor, select the fields you'd like to appear in the **Rows**, **Columns**, **Values**, or **Filter** categories of your pivot table report. (For purposes of this inventory system you can uncheck the "Show Totals" box in the menu box of each field.)
    - **Note**: You **cannot** add the same field to multiple categories of your pivot table report, as it would create duplicate calculations in the table.
5. To change how data is arranged in the table, you can drag fields to a different category. Click the **X** in the top right of a field to remove it from your pivot table report.

6. Utilizing the **Filter** Command you can select data ranges and choose which data values you wish the table to only show.

Pivot table reports have built-in settings to make it easier for you to analyze your data and to prevent you from ruining the pivot table report:

- The pivot table report will automatically add the values of each row and column into a grand total. Grand total summaries will appear at the right and to the bottom of your pivot table report.
- You cannot edit cell values by manually typing new values or by changing formulas in the pivot table report. Doing so would break the connection between the pivot table report and your original data set.

If you have created a pivot table in Microsoft Excel in the past, you can upload that spreadsheet to Google Spreadsheet. This allows you to continue to analyze your data using Google Documents no matter where you're signed in. To upload a Microsoft Excel spreadsheet that contains a pivot table, click the **File** menu, and select **Import...** Select from the import options, and click the **Import** button.

Linking Data from One Google Spreadsheet to Another

This feature can be useful when linking pivot tables from the main database to a separate Google Spreadsheet. This allows for the main user to create a sub database containing only certain information for different parties. The information will be linked and updated between the two spreadsheets, but data can only be modified on the original location and not the secondary file. As the command is typed a help box will appear and assist the user through typing the command.

Sample Usage

IMPORTRANGE("Web URL", "sheet1!A1:C10")

Syntax

IMPORTRANGE(spreadsheet_key, range_string)

- spreadsheet_key - In the Google Sheets, use the entire URL of the original Spreadsheet.
    - The value for spreadsheet_key must either be enclosed in quotation marks or be a reference to a cell containing the appropriate text.
- range_string - A string, of the format "sheet_name!range" (e.g. "Sheet1!A2:B6" or "A2:B6") specifying the range to import.

    - The sheet_name component of range_string is optional; by default IMPORTRANGE will import from the given range of the first sheet.
    - The value for range_string must either be enclosed in quotation marks or be a reference to a cell containing the appropriate text.

Notes

- A maximum of 50 IMPORTRANGE calls are supported on a single spreadsheet. This limit is removed in the new version of Google Sheets.
- In the new version of Google Sheets, the first time Spreadsheet B pulls data from Spreadsheet A, the person inserting the IMPORTRANGE will be asked to grant Spreadsheet B access to that data. Once access is granted, all other viewers and editors of Spreadsheet B will have access to the data being referenced by IMPORTRANGE.

See Also

IMPORTXML: Imports data from any of the various structured data types including XML, HTML, CSV, TSV, and RSS and ATOM XML feeds.

IMPORTHTML: Imports data from a table or list within an HTML page.

IMPORTFEED: Imports a RSS or ATOM feed.

IMPORTDATA: Imports data at a given url in .csv (comma-separated value) or .tsv (tab-separated value) format.

NOTE: Attempting to modify data linked from another sheet will cause an error, so do not attempt to modify data unless you're on the original sheet

Creating Dropdown Menu Choices

This creates easy to use dropdown menus for the database and controls the data values which could be inserted into the selected fields.

Follow these steps to create an in-cell dropdown list based on a range of cells or a list:

1. Select the cell or cells in which you'd like to create a dropdown list.
2. Under the **Data** menu, select **Validation...**.

3. In the dropdown menu next to "Criteria," select either **List from a range** or **List of items**.
    - If you selected **"List from a range,"** select a range of cells containing the values that will populate the list. If you change the contents of the range you've selected, the changes will be reflected in the list contained in the validated cell.
    - If you selected **"From a list,"** enter a set of custom values, separated by commas. For example, you could enter "peaches,plums,apricots,cherries." (Note: Don't use spaces after commas.)
4. By default, the cells you selected will contain an arrow button which, when clicked, will display the dropdown list. If you don't want the cells to display the arrow button, uncheck the checkbox that says "Display in-cell button to show list."
5. Click **Save**. The cells you chose to validate will now display a dropdown list with permitted values whenever a user edits the cell.

By default, people are allowed to enter data in a cell that doesn't match one of the items on the list. If they do, they'll see a warning. If you want to be stricter and allow people only to enter information from the list, choose "Reject input" next to the "On Invalid Data" option.

Note our recommendations for all actions on the Google Spreadsheet were provided by Google Help:

https://support.google.com/docs/answer/37579?hl=en

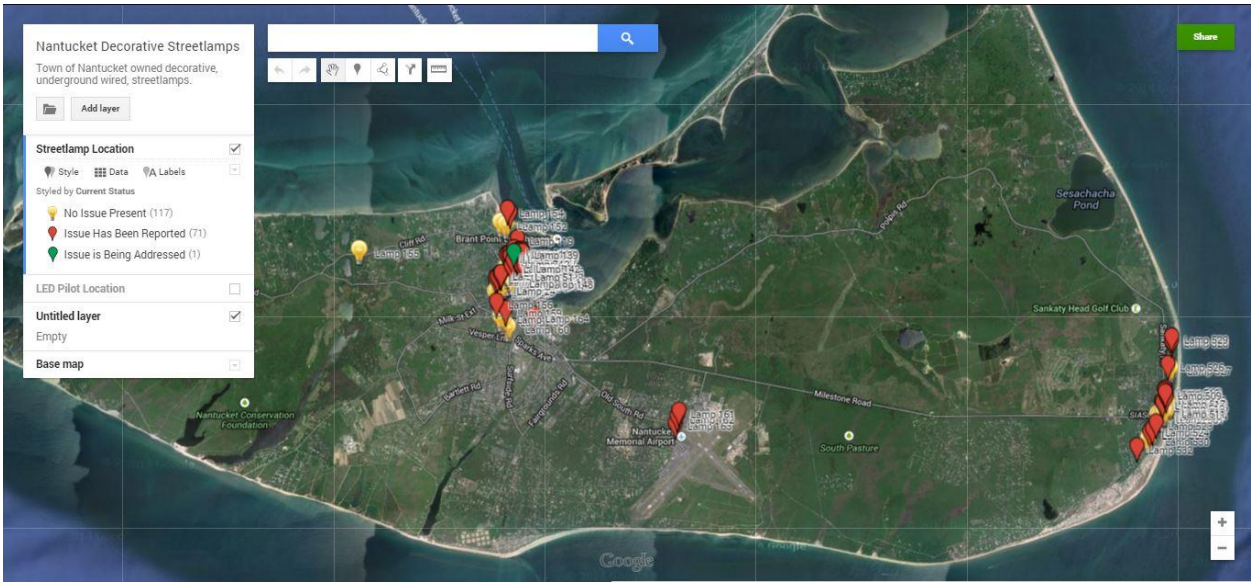
https://support.google.com/docs/answer/1272900?hl=en

https://support.google.com/docs/answer/3093340?hl=en

https://support.google.com/docs/answer/186103?hl=en

Appendix G: Interactive Map Manual

Streetlamp Interactive Map Instructional Guide



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Key Commands for Interactive Map

Changing the Current Status of the Decorative Streetlamps

To change the "Current Status" field to indicate the status of the streetlamps, the wording and capitalization are crucial. Everything should be consistent throughout the input for the streetlamps to change the icon appropriately.

1. Click on the streetlamp of interest on the map. A box will appear with the data for that streetlamp.
2. Click on the  icon at the bottom of the box to edit. This will allow the user to make changes to the data shown.
3. The "Current Status" field can be changed to either "No Issue Present," "Issue Has Been Reported," "Issue is Being Addressed," and "Remove From Inventory." Type the options exactly as shown without the quotations.
4. If the field is being changed from "**No Issue Present**" → "**Issue Has Been Reported**":
    a. Provide a brief description of what is being reported in the "Issue Reported" Category
    b. Provide the date the report was submitted in the "Date Reported" Category
5. If the field is being changed from "**Issue is Being Addressed**" → "**No Issue Present**":
    a. Provide the date of when the issue was resolved in the "Last Inspection" Category
6. Click **Save**

Managing Layers on My Maps

Adding a layer to My Maps allows the user to organize different sets of data on multiple layers.

Adding a layer: Click on the **Add layer** button on the left side of My Maps. My Maps allows the user to have up to 5 layers for the free version.

Hide or unhide a layer: Click the checkbox on the right side of the layer title. The layer is hidden when there is no check in the checkbox and everything in that layer won't be visible. The layer is unhidden when there is a check in the checkbox and everything in that layer will be visible.

Deleting a layer: Click on the layer that you would like to delete and a dropdown menu will appear below the checkbox for viewing the layer. Next, click on the dropdown menu and select **Delete this layer.**

Adding an Icon or Plot to My Maps

Once a layer is established, you can start plotting icons on the map.

1. Click on the  button near the top of the map. This allows the cursor to pick the location.
2. Click on the location you would like the icon to be.

If the location you would like to add the icon is not in view:

1. Click on the  (hand) button to maneuver around the map to the desirable location.
2. Then, click on the  button and then click on the location of interest.

Deleting an Icon or Plot from My Maps

If the icon is no longer needed or at an undesirable location:

1. Click on the icon you would like to delete and a box should appear.
2. Click on the  (trashcan) icon at the bottom right of the box and the icon will be deleted from My Maps.

Undo and Redo Options

To undo action: Click on the  button located near the top of the map.

To redo action: Click on the  button located near the top of the map.

Changing the Appearance of the Icon

Once an icon is plotted, the user has the option to customize the icon appearance that will best fit the user's need.

1. Choose the layer you want to work with.
2. Click on the  icon.
3. Click on the dropdown menu you can chose the four options: "**Uniform Style,"** "**Sequence of color and letters," "Individual Style,"** and **"Style by data column."**
4. **Uniform Style** keeps all icons appearance consistence. You can customize the icon.
5. Bring the cursor to the possible input and you'll see a paint bucket.
6. Click on the bucket if you would like to customize the icons to a different shape, color, or even download another icon online (with a URL).
7. **Sequence of color and letters** allows each icon to have a different letter and color. You can still customize the icons like above.
8. **Individual Style** allows each icon to have a different icon appearance. The user has the ability to customize each individual icon.
9. **Style by data column** allows the icon appearance to change according to its input in a particular category. This option is explained in the "Changing the Icon Based on Certain Category" section of the manual.

Changing the Icon Based on Certain Category

My Maps allows the user to change the style of the icon based on a selected category. This feature enhances the visualization for the viewers and helps present a certain data quickly.

1. Choose the layer you want to work with.
2. Click on the  icon.
3. Click on the dropdown menu.
4. Underneath the **Style by data column,** it will list all the categories currently in the Data Table.
5. Choose one of the categories you would like to icon appearance to depend on.
6. Choose whether you would like to icon the change depending on the **Ranges** (numerical) or **Categories** (alphabetical).
7. Depending on the variation of data that particular category has, My Maps will group the icon according to the input of that category.
8. Bring the cursor to the possible input and you'll see a paint bucket.

9. Click on the bucket if you would like to customize the icon to a different shape, color, or even download another icon online (with a URL).
10. Any additional icon added later on will change accordingly to the icon appearance if it shares the same input for that particular category.

Modifying Categories in the Data Table

The user can manipulate the categories to the Data Table, such as viewing, adding, deleting, sorting the column.

To view Data:

1. Choose the layer you want to add a category to.
2. Click the **Data** icon on the left side. You can view all the data inputs but scrolling left to right or up and down.
3. The user can search for the streetlamp of interest by typing its name in the searching box above the data.

To add data to the Data Table:

1. Choose the layer you want to add a category to.
2. Click the **Data** icon on the left side.
3. Type in the data for each icon and the information will automatically save. The data will also automatically change for the icon.
4. Data can be added to the icon when the icon is clicked on.
5. Click on the icon to edit any information.

To sort Data:

1. Choose the layer you want to add a category to.
2. Click the **Data** icon on the left side.
3. Clicking on the dropdown menu located near the title of the category the user would like to sort the data.
4. Click on the one of the sorting options "**Sort A -> Z**" or "**Sort Z -> A**".

To insert a new category:

1. Choose the layer you want to add a category to.
2. Click the **Data** icon on the left side.
3. Click on the dropdown menu located near the title of the category the user would like to sort the data.
4. Decide the existing categories you would like the new category to be near.
5. Click on the dropdown menu located near the title of one of the existing category.
6. Choose either the "**Insert column before**" or "**Insert column after**" to place the new category.
7. Insert the column name and choose of the type of data the column will have from the dropdown menu (ex. Text, Number, Date, etc.)

To delete a category:

1. Choose the layer you want to add a category to.
2. Click the **Data** icon on the left side.
3. Click on the dropdown menu located next to the title of the category the user would like to delete.
4. Choose "**Delete column**" on the dropdown menu.

Select Data Viewing for the Public

A lot of data can be added to the Data Table but the user can allow the public to view certain data only.

1. Click on any icon on the map. A box will appear with categories for the icon.
2. Next to each category is a checkbox.
3. Click on the checkbox. If the checkbox has a check mark then the category can be seen by the public. If the checkbox does not have a check mark then the category cannot be seen by the public.
4. This will affect all the icons on that layer.

Sharing the Interactive Map with Others

The My Maps can be shared to others through their emails. The user can allow whether the individuals can edit or view the map.

1. Click on the **Share** button on the top right corner of the map. A box will appear.
2. Type the email addresses of the individuals you would like to share access to the map in the text box at bottom.
3. Choose the access level from the dropdown menu next to the individual. The two options are “Can view” and “Can edit.”
4. Another method is to share using the URL provided near the top of the box.

Note our recommendations for some actions on the Google My Maps were provided by My Maps Help:

https://support.google.com/mymaps/answer/3024933?hl=en

https://support.google.com/mymaps/answer/3024931?hl=en

https://support.google.com/mymaps/answer/3024968?hl=en