Case Study: Falmouth Lighting Retrofit Analysis
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Energy Efficiency 311

# Falmouth Lighting Retrofit Analysis

## I. Introduction

In recent history humanity has been meeting its energy demands by the combustion of fossil fuels at rate much faster than can be replenished resulting in a plethora of environmental consequences from climate change to reduced air quality and societal consequences of energy scarcity, inequality and economic burden (Ebenhack & Martinez, 2013). While progress has been made in researching and developing different primary energy sources that do not produce the same atmospheric emissions or require a finite stock dependent input, those energy sources current production potential is just a minute fraction of the demand (Ebenhack & Martinez, 2013). However, in 2015 the overall US power plant energy efficiency (energy content of fuel in: unit of work produced) was 31.74% and some end use conversion devices efficiency are even lower-the incandescent light bulb is between 2-5%-resulting in a cumulative system efficiency of roughly 1% (Martinez, Lecture, September 2019). Therefore, the greatest and most immediate energy savings can be obtained by improving the efficiency of energy conversion through technological improvements in conversion devices or improvements to processes (Martinez, Lecture, September 2019).

Lighting is the most energy intense conversion in commercial buildings and accounts for 20% of a building's electricity use (Department of Energy, 2011). Commercial indoor lighting accounts for 6.3% of the US total electrical use in 2015 (Buccitelli, Elliott, Schober & Yamanda, 2017). However, new lighting technology, such as compact fluorescent lamps (CFLs) and light emitting diodes (LEDs) have improved the potential energy efficiency of the incandescent bulb by 25-80% (DOE, 2019) as well as increased the lifespan of the product resulting in potential financial and emissions savings when buildings are retrofit with the newer, more energy efficient technologies.

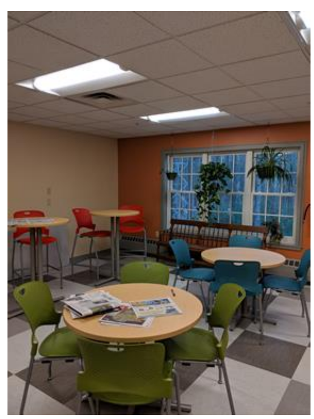
Municipalities are responsible for not only the lighting of their commercial buildings but also the outdoor lighting of their streets and public spaces. While indoor lighting supports the productivity of municipal employees and processes outdoor lighting's primary purpose is public safety and is associated with fewer motor vehicle accidents and lower crime rates (UC Davis Energy Efficiency Center, 2015). In California outdoor lighting represents 25-50% of municipal energy budgets (UCSEEC, 2015) and accounts for 5.4% of total US electricity use in 2015 (Buccitelli et al., 2017). Indoor and outdoor lighting combined represent an enormous opportunity to improve the energy efficiency with direct financial and emission savings.

## II. Background

In the spring of 2019, the Town of Falmouth completed a lighting retrofit of both indoor and outdoor municipal lighting. In the phase 1 of the interior lighting retrofit plan the Town included the Town Hall, the Police Department (which also houses information technology infrastructure), the Public Works Department and 3 fire stations. Together the buildings in phase 1 totaled 66,507 square feet and spanned multiple functions, from the office space in the Town Hall, industrial space of the Public Works Sand Shed to the residential spaces of the fire stations. All existing lighting was removed including (but not limited to) emergency lighting, illuminated emergency signage and outdoor building lighting. The fluorescent, CFLs and high intensity discharge (HID) lights that were removed were replaced with a comprehensive lighting design that included LEDs, manual dimmers, motion sensors and daylight harvesting technology. The project cost $237,870, $33,510 of which the Town recaptured through Efficiency Maine incentives, resulting in a net capital purchase of $203, 960 by the Town. In 2018 the phase 1 buildings consumed 505,831 kWh of electricity and the Town spent $62,699 on all electricity consumption in phase 1 buildings. A simple back of the envelope calculation estimates that the LED retrofit would reduce the electricity consumption by 16%.

Outdoor Building Lighting

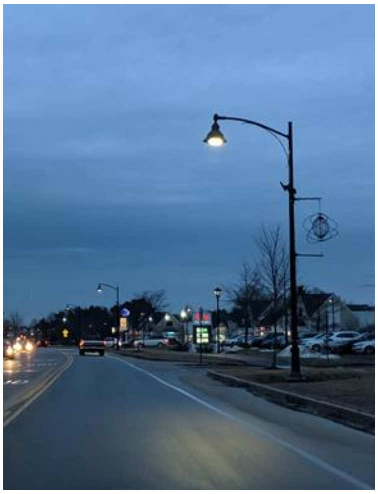

Sand Shed Lighting


Office Lighting

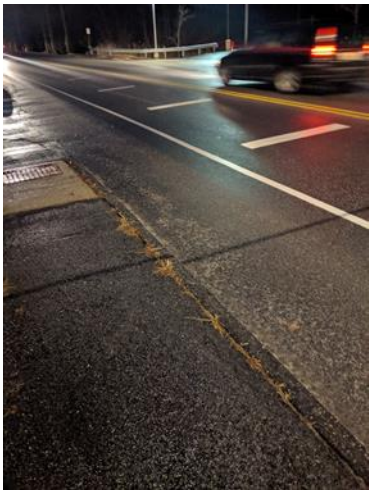

Emergency Lighting

At the same time the Town sought to replace 498 high pressure sodium (HSP) cobra streetlights and 131 HSP outdoor decorative lights within its municipality. Prior to the retrofit the Town leased the outdoor lighting equipment from the utility company, Central Maine Power, and paid a monthly leasing fee as well as purchasing the electricity delivered. In 2018 the Town consumed 302,793 kWh and spent $85,730 on leasing the equipment and the electricity consumed. Prior to the retrofit the Town sued CMP for the right to replace the equipment with technology of their choosing. The Public Utilities Commission ruled in the Town's favor but stipulated that the Town must first purchase the equipment from CMP prior to removing it and replacing it. The Town purchased the existing lights for $42,618 and the new equipment and installation costs totaled $385,590. The net outdoor retrofit cost was $428,208 which the Town paid for outright.

Outdoor Decorative Lighting



Outdoor Decorative Lighting



Cobra Streetlamp Illumination

III. Procedure, Results & Analysis

Monthly utility bills for outdoor lighting and indoor lighting were compared from 2018 and 2019. The indoor lighting data was analyzed individually and aggregated. At the time of the analysis 2019 bills were available January thru October. In January to October 2019, the indoor kWh consumption for all phase 1 buildings was 391,048 kWh a realized reduction of 28,844 kWh or 6.4% compared to the same 10-month period in 2018.

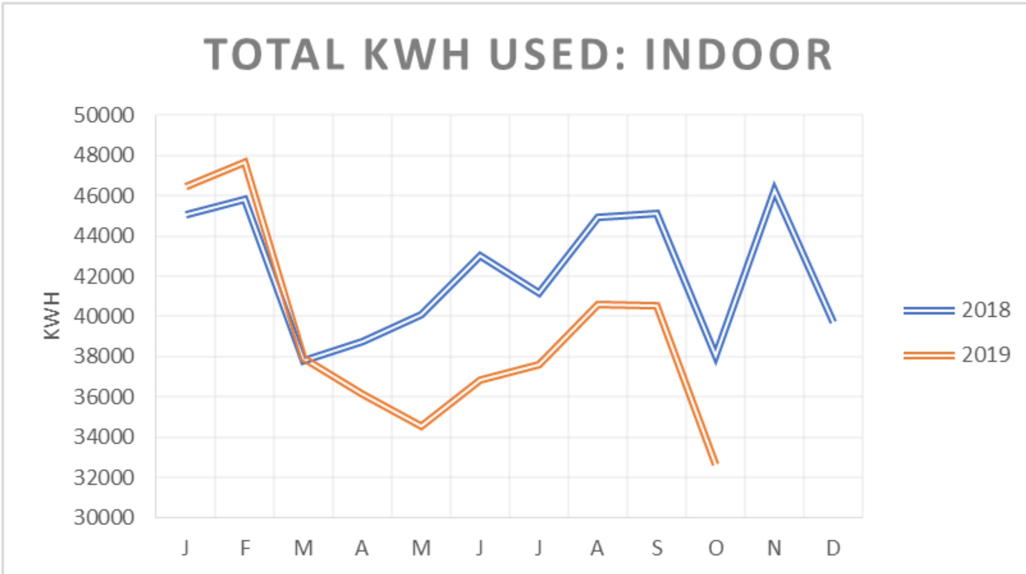



Figure 1. Phase 1 buildings aggregated kWh comparison 2019:2018

The associated realized financial savings were $7,320 for the 10-month comparison. The associated realized reduction of atmospheric pollutants were 591 tons of $CO_2$ and 2 tons each of Nitrous Oxides and Sulfur Oxides.

Table 1. Realized Savings from Indoor Retrofit January to October

| | January-October (Realized) | | |
|---|---|---|---|
| | 2018 | 2019 | Savings |
| kWh | 419892 | 391048 | 28844 |
| Dollars | $51,345.69 | $44,025.39 | $7,320 |
| $CO_2$ (tons) | 8608 | 8016 | 591 |
| SOx (tons) | 25 | 23 | 2 |
| NOx (tons) | 25 | 23 | 2 |

However, the buildings' utility bills aggregate all the electricity use, including telecommunications use, heating ventilation and air conditioning (HVAC) use and other electrical uses. Additionally, the climate conditions from 2018 to 2019 are not identical and it's likely the savings from the lighting retrofit are greater than what is apparent from the utility bills. Figure 1 shows that the total kWh use in the first 2 months of 2019 (prior to the retrofit) was 3.0% higher than the same months in 2018. This could indicate an increase in baseline services provided, whether increased hours of service, increased space or increased functions (new equipment or new demand).

Additionally, when the buildings are examined individually and by month a seasonal variation is identified. The kWh use is increased during the summer months and in some buildings the 2019 kWh use in summer months exceeds the use during the same period in 2018. Department directors of the outlying buildings reported new window AC use (Foreside & Winn Fire), increased hours of service (students living at the Foreside & Winn station in 2019 but not 2018) and concern that the HVAC system wasn't functioning properly (Public Works).

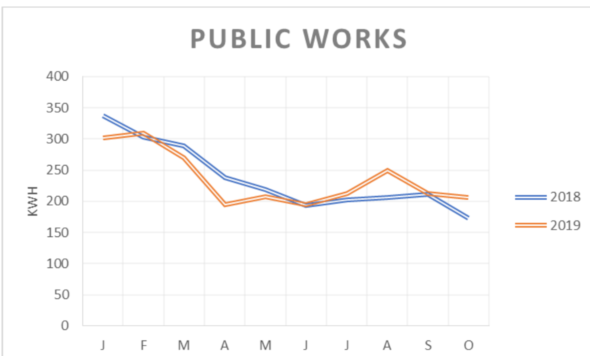



Figure 2. Monthly kWh 2018-2019: Public Works

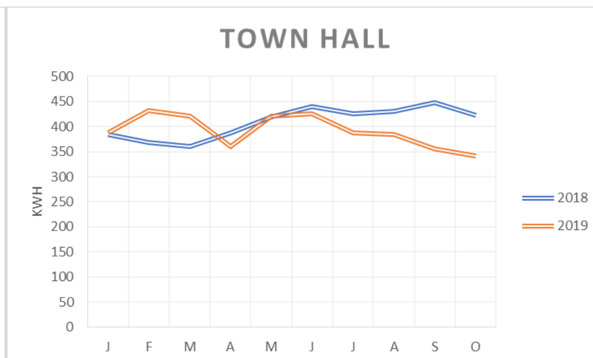



Figure 3. Monthly kWh 2018-2019: Town Hall

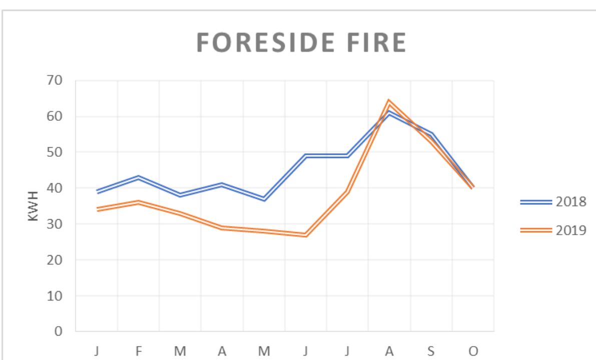



Figure 4. Monthly kWh 2018-2019: Foreside Fire

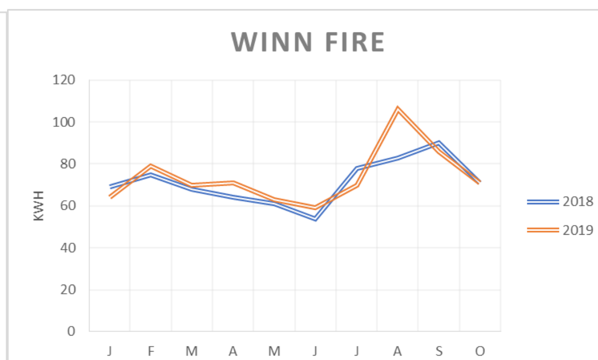



Figure 5. Monthly kWh 2018-2019: Winn Fire

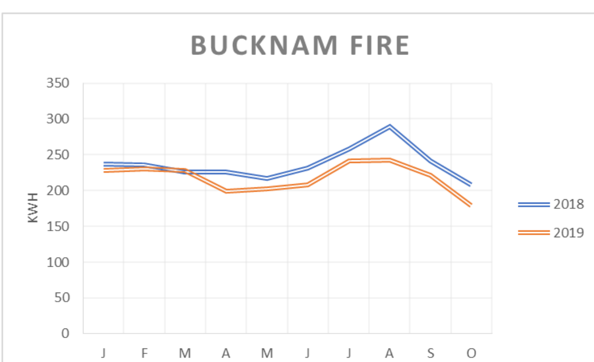



Figure 6. Monthly kWh 2018-2019: Bucknam Fire

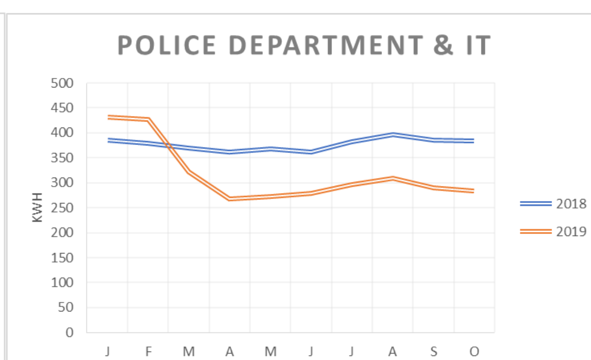



Figure 7. Monthly kWh 2018-2019: Police Department & IT

However, historical climate data shows that 2019 had more cooling degree days than 2018 and it's possible that some of the decrease in overall kWh savings was due to universal increased demand for cooling as well as an increase in cooling utilization. Therefore, at minimum, kWh used for cooling need to be removed from the aggregate data in order to analyze the energy savings from the lighting retrofit. The differences in kWh between 2019 and 2018 in non-cooling months were isolated and used to create an adjusted annual savings. The adjusted annual energy savings is 80,479 kWH with an associated financial savings of $12,560 per year. Including the estimated reduction in maintenance costs of $5,770 per year the estimated payback period is 11 years and the return on investment is 2.07 over 23 years.

Table 2. Adjusted Indoor Retrofit Financial Summary

| Indoor LED Retrofit Financial Summary | |
|---|---|
| Total Costs: | $237,870 |
| Efficiency Maine Incentives: | $33,510 |
| Net Project Costs: | $203,960 |
| Annual kWh savings: | 80,479 |
| Annual energy cost savings: | $12,554.72 |
| Annual maintance cost savings: | $5,770 |
| Annual savings: | $18,325 |
| Estimated payback period (yrs): | 11 |
| Simple Return on Investment: | 2.07 |

Table 3. Adjusted Atmospheric Pollutant Savings 2019

| Atmospheric Pollutant Savings | |
|---|---|
| kWh | 80479 |
| CO2 (tons) | 1650 |
| Sox (tons) | 4.8 |
| NOx (tons) | 4.8 |

The efficiency of the outdoor lighting retrofit was analyzed in a similar fashion, by comparing utility bills by kWh used and financial sum billed. However, given that the kWh delivered was a product of the lighting and no other energy use the energy savings were far clearer and closer to the estimated savings made prior to the retrofit. Additionally, the financial savings was greater as the Town not only realizing savings on the reduced kWh delivered but also on the leasing fees. In May thru October the outdoor lighting energy use was decreased by 99,857 kWh with an associated financial savings of

$42,536. The projected annual savings is 208,766 kWh and $74,360. The estimated payback period is 5.8 years and the return on investment over a 23 year period is 3.99.

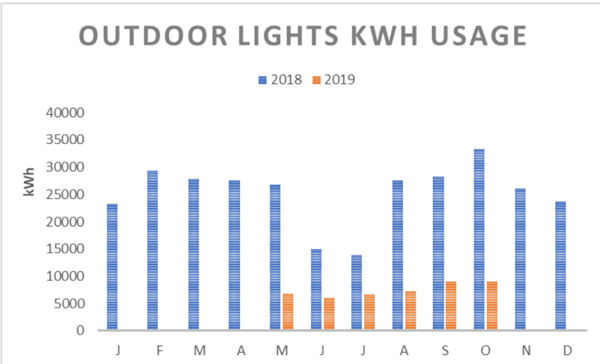



Figure 8. Outdoor Lighting Retrofit kWh Use 2018-2019

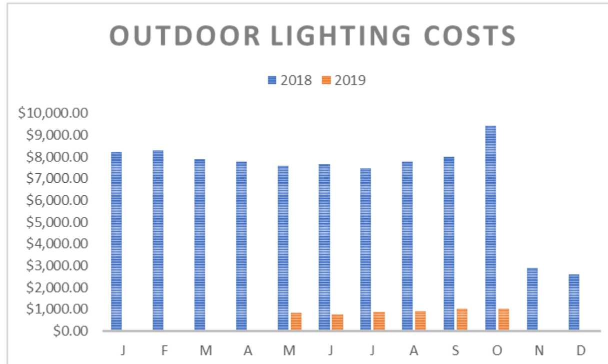



Figure 9. Outdoor Lighting Retrofit Costs 2018-2019

Table 4. Outdoor Lighting Retrofit Financial Summary

| Outdoor Lighting LED Retrofit Financial Summary | |
|---|---|
| New Equipment Purchase & Installation: | $385,590 |
| Old Equipment Acquisition Costs: | $42,618 |
| Net Project Costs: | $428,208 |
| Annual kWh savings: | 208,766 |
| Annual energy cost savings: | $27,139.58 |
| Annual equipment leasing fees: | $47,221.98 |
| Annual savings: | $74,362 |
| Estimated payback period (yrs): | 5.8 |
| Simple Return on Investment: | 3.99 |

In terms of atmospheric pollutants the realized reduction from May to October was 2,047 tons of CO2 and 6 tons each of Nitrous Oxides and Sulfor Oxides. The estimated annual reduction was 4,280 tons of CO2 and 12 tons each of Nitrous Oxides and Sulfor Oxides.

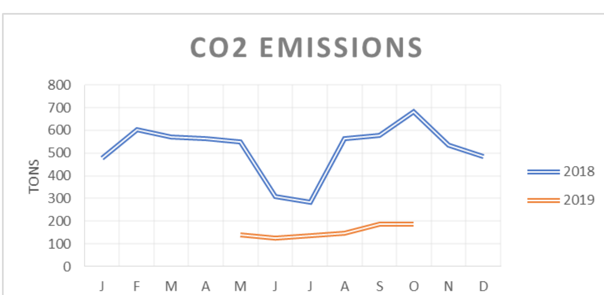



Figure 10. Actual CO2 Emissions 2018-2019

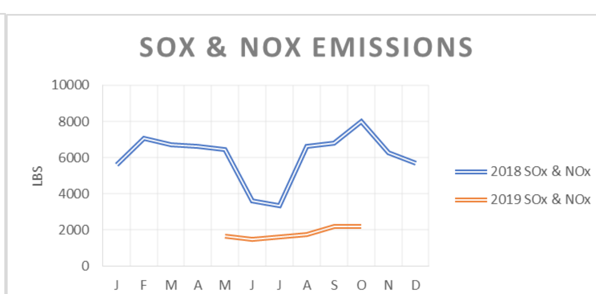



Figure 11. Actual SOx & NOx Emissions 2018-2019

## IV. Disscussion

The Town of Falmouth realized energy and financial savings as expected with the outdoor lighting retrofit. However, the energy and financial savings from the indoor lighting retrofit are less clear as there are more confounding variables with the mixed-use buildings and varied functions aggregate energy use. However, given trends in the seasonal variation seen across all buildings it would be beneficial to further analyze energy used by cooling devices and systems whether by calculating the difference in cooling degree days between the years or by comparing energy consumption rates between buildings that have been retrofit and buildings that have not been retrofit with LED lighting. Due to the temperature variation between years as well as difference in human behavior between years it is not possible to get a very precise savings total by comparing current use with historical use. The Town of Falmouth may be further interested in a cooling energy use analysis as it appears to be the next driver in the municipal electricity consumption.

## V. Appendices

i. Excel Worksheets (attached)

ii. Technology Specification sheets for lighting design

References

Buccitelli, N., Elliott, C., Schober, S. & Yamada, M., (2017). *2015 U.S. lighting market characterization.* (Office of Energy Efficiency & Renewable Energy). Washington, DC

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