LED Lighting:

Carbon Footprint Reduction and Energy Cost Savings
at
Prince George's County Parks and Recreational Facilities

Derin Belanger, Parhum Ghassemi, Nina Jefferies, Matthew McClanahan,

Alison Snider, Jock Thompson

Under the supervision of Dr. Mark Carroll

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Gerrit Knaap, NCSG Executive Director

Kimberly Fisher, PALS Director

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I. Executive Summary

The Prince George's County Department of Parks and Recreation strives to enhance the quality of life for county residents by promoting healthy lifestyles and providing enriching leisure services. In keeping with this mission, the Division of Maintenance and Development within the park system has partnered with Environmental Science and Policy capstone students at the University of Maryland College Park to examine the cost and energy savings when LED lighting, and other energy-saving devices, are used at park system facilities. The facilities analysis will allow Prince George's County Department of Parks and Recreation to uphold the values of a healthy lifestyle while still providing enriching leisure services.

The LED lights student group was tasked with exploring the potential for carbon footprint reduction using LED lights as well as other energy-saving devices. The analysis was accomplished using three objectives. The first was to identify four facilities administered by the Department of Parks and Recreation with the information necessary to accurately assess their electrical energy usage and the impact of retrofitting. The team also evaluated facilities with similar functions and sizes, and selected the Seat Pleasant Community Center, Vansville Neighborhood Recreation Center, Huntington Community Center, and Palmer Park Community Center. These have similar functions, which made them candidates for comparison.

The second objective was to examine the projected and actual energy savings at two facilities as a result of conversion to LED lighting. This was completed using consultant data provided by the Department of Parks and Recreation, along with calculations to compare the projected energy savings, based on each building's square footage, and the difference in energy use in the months of June, July, and August of 2019 and 2021. The results showed a larger difference in projected cost and energy savings (electricity bills) for retrofitted facilities, however the results were not consistent. The results also showed that, across the board, actual cost and energy savings were less than projected.

The final objective was to determine the realized and potential carbon footprint reduction from a switch to LED lights, including carbon reduction from additional energy-saving technologies (motion sensors, automatic lights, etc.). This was completed by conducting a comprehensive life cycle analysis (LCA) using peer reviewed literature on LED lifecycles. The analysis shows that retrofitting facilities with LED lights will always result in lower electricity usage and carbon emissions. However, the proportion of the effects will vary depending on the share of total emissions that are from lighting. Simply put, retrofitting facilities with LED lights can drastically reduce carbon emissions. Although the impact is more significant in facilities where lighting is a larger proportion of electricity usage.

II. Introduction

Why LED Lights?

Climate change describes how the typical observed patterns of weather and temperature are changing (*What is Climate Change*, United Nations). Climate change has been caused by the rapid increase of greenhouse gases (GHGs) in the atmosphere, of which carbon dioxide is the most abundant. The effects of climate change are dangerous and threaten the stability and long-term viability of our planet. In Maryland, these effects include increased precipitation, increased flooding, increased temperature contributing to heat illness and death, lower air quality, and rising and retreating shorelines (*What Climate Change Means for Maryland*, EPA).

A major source of GHG emissions is electricity generation. The Environmental Protection Agency reported that in 2019, 25% of the country's GHG emissions come from generating electricity (*Sources of Greenhouse Gases*, EPA). Of the electricity generated in Maryland, the largest amounts by source are natural gas, nuclear, and coal, respectively. In 2019, only 11% of electricity generated in the state came from renewable energy (*Maryland*, U.S. Energy Information Administration). Two recognized ways of reducing carbon emissions from electricity are retiring fossil fuel while switching to renewable energy sources and reducing electricity consumption.

Light Emitting Diode (LED) lights are one way to reduce electricity usage. As an alternative to incandescent and fluorescent light bulbs, LEDs require fewer watts and produce less heat to create lumens (visible light) (*LED Lighting: A Cost-Benefit Analysis*, Starbeam Lighting Solutions). The United States Department of Energy (DOE) reported that switching to LED lighting, can use "at least 75% less energy, and last up to 25 times longer, than incandescent lighting" (U.S. DOE). Reduced heat generation, the low electricity draw, and LEDs' solid-state components all contribute to their longer life compared to incandescent lighting.

In Maryland, electricity generated and delivered to point of use produced 0.841 lbs. CO_2 eq/kWh in 2018 (*Emissions & Generation Resource Integrated Database (eGRID)*, EPA). This value considers the production of CO_2, CH_4, and N_2O in the generation, transmission, and delivery of electricity with 99% of contribution coming from the production of CO_2. Carbon savings arising from the reduced electricity use can be calculated over a prescribed time period using the former value (0.841 lbs. CO_2), however a complete picture of the possible carbon savings from any light source requires evaluating the lighting source's use phase as well as its production and end-of-life stages. This kind of cradle-to-grave evaluation of a material is referred to as life cycle assessment (LCA), which encompasses an examination of multiple environmental impacts and the process itself and is considered the most rigorous and insightful evaluation of a product's sustainability.

LED Lights and Prince George's County Parks and Recreation Department

Last spring, Prince George's County committed to producing a climate action plan by the end of September 2021 (*Climate Change*, Prince George's County Government*)*.The Prince George's County Parks and Recreation Department (PGCPR) has also instituted its own goals to reduce its environmental impact and support sustainability (*Our Sustainability Goals,* PGCPR).

These goals include:

- 60% reduction in carbon emissions (from 2005 levels) by 2025
- Carbon neutrality (net-zero carbon emissions) by 2040
- Total electricity consumption reduced by 30% by 2025 through infrastructure upgrades and behavior change initiatives.

LED lights can be an important component to meet these goals of reduce carbon emissions, achieving carbon neutrality, and reducing electricity consumption.

Reducing the amount of electricity needed for lighting contributes to reducing total electricity consumption. Projecting the amount of energy saved by replacing existing fluorescent or incandescent lights with lower-energy-using LEDs is a relatively straightforward calculation, however other indirect energy savings such as the reduced cooling cost associated with the lower heat generated by LEDs is more difficult to assess. Other building characteristics such ceiling height, insulation, and ventilation may override the beneficial thermal properties of LED lights. Nevertheless, a wholesale retrofit of building lighting should generate a decrease in electricity consumption detectable by comparing utility bills before and after the retrofit. Performing such a check in electricity usage can reveal if cost and carbon savings are being realized as anticipated. Assessing carbon savings is important to help municipalities document progress in meeting their carbon reduction goals.

Given this relationship between LED lights and meeting energy goals, this report details an examination of the cost and carbon savings of switching to LED lights in facilities run by the Prince George's County Parks and Recreation Department, specifically community centers.

III. Goals and Objectives

1. Identify four facilities with the information needed to accurately assess electrical energy usage and the impact of retrofitting.

2. Examine the projected and actual cost and energy savings at two facilities as a result of conversion to LED lighting and the addition of light control sensors.

3. Determine projected and actual carbon footprint reduction that result from switching to LED lights, including carbon reductions from energy-saving technologies such as motion sensors and automatic lights.

IV. Methodology/Research Approach

Objective One

To identify four facilities that could be assessed for the energy and cost savings of an LED retrofit, the facilities must be similar in function and size. Both retrofitted and non-retrofitted facilities must be evaluated to compare the energy and cost savings of switching to LED lighting. It is important that the facilities have similar functions, so their usage and energy consumption are consistent.

The selection of facilities was based on input from with the Department of Parks and Recreation and consultant firm data, that identified two retrofitted community centers and two-non retrofitted community centers. Proximity to the University of Maryland, College Park was also considered in case of site visits. The four buildings chosen are Seat Pleasant Community Center, Vansville Neighborhood Recreation Center, Huntington Community Center, and Palmer Park Community Center.

Objective Two

Energy Savings
Electric use statements for the identified facilities were obtained for billing months of June, July, and August in 2019 and 2021. Between 2019 and 2021, two of the facilities were retrofitted with LED lighting. In one facility, several motion sensors were part of the lighting retrofit.

Because the dates and length of the billing period varied by as much as five days between the two years, all electricity use data were converted to units of kWh/day. The data were further normalized to consider facility size, resulting in the final electric usage for the billing period being expressed as kWh/day ft^2.

Actual energy savings in lighting costs was estimated by first determining the change in monthly electricity use between 2019 and 2021 at the two facilities where no change in lighting occurred. This represented the expected change in electricity demand resulting from variations in weather and pedestrian traffic. Any additional change in electricity usage from the average in the two non-retrofitted facilities was attributed to changes in the amount of electricity used to power lights at the retrofitted facilities.

Projected electricity savings from LED lighting was based on itemization of the energy savings for each light in the facility replaced with an LED light. The projected energy savings were obtained from the consultant data. Annual, individual light use was determined by multiplying the power consumption of a light by the annual projected hours of operation. Daily light energy use was calculated by dividing the annual hours of operation by 365. Carbon emissions arising from electricity use was calculated by multiplying electricity use by the Maryland carbon emissions factor (0.841 lb CO2 eq/kWh).

Cost Savings

The consultant data includes a calculation of the projected cost savings for the two retrofitted facilities. With that information, the team was able to calculate the percentage difference between projected and actual cost savings. The kWh savings per day was calculated by finding the difference in light energy pre- and post-retrofit. After finding kWh savings per day, the team used the utility bills from June, July, and August of 2021 to determine the number of days in the billing period and the cost of kWh for that billing period. Using the utility bills, the team found the actual cost savings for each month. From that, the percentage difference between projected and actual cost savings could be interpreted. (See the Appendix for complete calculations.)

Objective Three

A comprehensive life cycle analysis assessed the carbon footprint impact of LED lights during the use and disposal timeframes of the LED lifecycle. This analysis was based on peer-reviewed literature on LED lighting and provided information to create the assumptions needed to determine the carbon footprint impact of LED lights. For the usage phase of the life cycle (which has the greatest impact), carbon savings are determined by the difference in kilowatt-hours consumed and the EPA's regional emissions factor. In non-retrofitted facilities, the same formula can be used to find the projected reduction in carbon emissions. (See the Appendix for complete calculations.)

V. Results and Findings

Objective One: Facility Selection

Useful results would be based on compaing buildings that are retrofitted and non-retrofitted, and similar in function and size. Two retrofitted facilities, Seat Pleasant Community Center (18,200 sq. ft.) and Vansville Neighborhood Recreation Center (4,100 sq. ft) were compared with two non-retrofitted facilities, the Huntington Community Center (20,000 sq. ft.) and Palmer Park Community Center (32,000 sq. ft.). These facilities are all community and/or recreation centers and are viable candidates for comparison.

LED Retrofit: Energy Consumption Changes and Cost Savings

Table 1
Difference in kWh/day/sq. ft. for each facility (using June/July/Aug energy bills)

Energy Usage (kWh/day ft2)	6/19	6/21	Difference (kwh/day ft2)	7/19	7/21	Difference (kwh/day ft2)	8/19	8/21	Difference (kwh/day ft2)
Seat Pleasant (retrofit)	0.04259	0.03004	0.01255	0.05086	0.03689	0.01398	0.04398	0.03700	0.00698
Vansville (retrofit)	0.04527	0.02564	0.01963	0.05079	0.02511	0.02567	0.03793	0.02483	0.01309
Huntington (non-retrofit)	0.03693	0.02958	0.00735	0.04106	0.02959	0.01148	0.03887	0.02948	0.00940
Palmer Park (non-retrofit)	0.06200	0.04131	0.02068	0.06554	0.03932	0.02623	0.05284	0.04729	0.00555

Based on billing data, Table 2 shows the difference per day per kWh per sq. ft. with the retrofitted and non-retrofitted facilities averages.

Table 2
Difference kWh/day/sq. ft. with average retrofit and non-retrofit

	June	July	August
	Difference (kwh/day ft2)		
Average non-retrofit	0.01402	0.01885	0.00747
Seat Pleasant Community Center (retrofit)	0.01255	0.01398	0.00698
Vansville Community Center (retrofit)	0.01963	0.02567	0.01309
Average retrofit	0.01609	0.01983	0.01003

The data collected from utility bills shows the difference in electricity usage from 2019 to 2021 was larger for the retrofitted facilities in all months. The data also shows that Vansville experienced a more dramatic reduction than Seat Pleasant. This could be for a variety of reasons. It could be that Seat Pleasant uses more of its purchased electricity for heating, cooling, cooking, computer or game systems, or other uses besides lights. Or it could be the case that Vansville uses more of its electricity on lights than other community centers.

Figure 1 shows electricity savings in 2021 for the two retrofitted facilities.

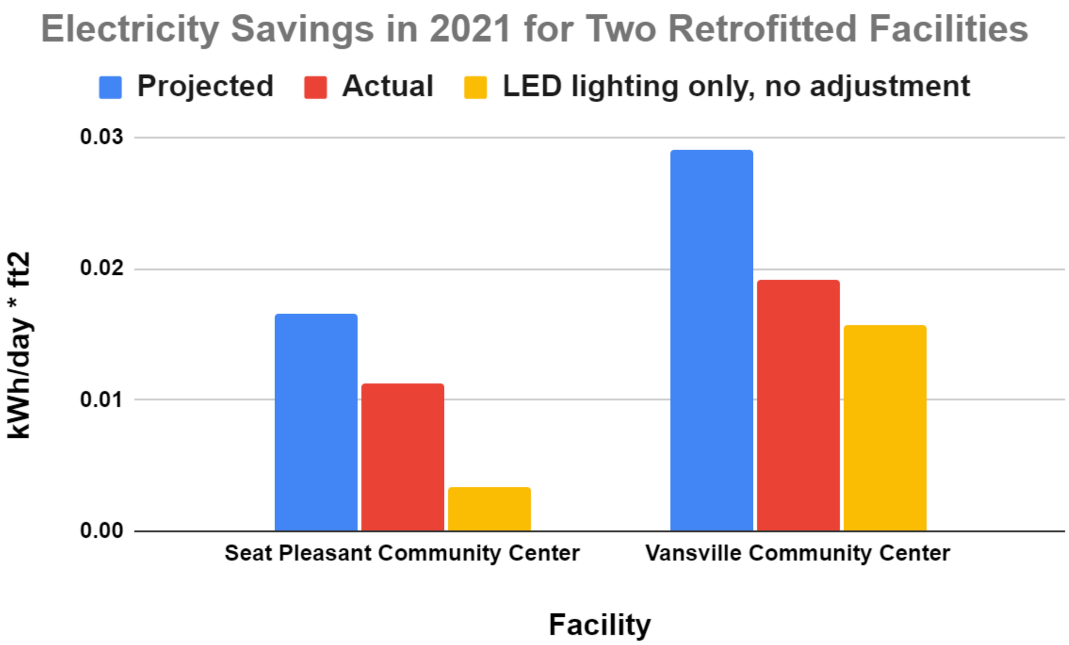

Figure 1
Electricity savings in summer 2021 for retrofitted facilities (kWh/day/sq.ft.)

Electricity savings were observed in both facilities, however, the savings were less than predicted by the consultant data. The blue bar shows projected electricity savings from the consultant data plus difference in electricity usage between 2019 and 2021. The red bar shows observed electricity savings, and the yellow bar estimates how much of the electricity savings can be attributed to the LED retrofit. For Vansville, reduction in electricity usage played a large part in reducing kWh usage per day per square foot. For Seat Pleasant, the LED retrofit played a smaller role.

Some of electricity usage reduction can be attributed to changes in occupancy due to the COVID-19 pandemic. In fact, most of Seat Pleasant's reduction might be attributed to this, and it could explain why the LED retrofit made relatively little difference in reducing electricity consumption as compared to Vansville.

Objective 2: Cost Savings Result

The cost savings findings varied for retrofitted facilities. For Vansville, the actual cost savings were significantly higher than the projected cost savings, as shown in Figure 2. To be exact, there was a 22.7% increase in actual cost savings in June, a 107.5% increase in actual cost savings in July, and a 135.1% increase in actual cost savings in August. Seat Pleasant showed different results as the actual cost savings were less than the projected cost savings, shown in Figure 3. The actual cost savings in June was 15.9% less than the projected cost savings, in

July it was 20.9% less than the projected cost savings, and in August it was 23.2% less than the projected cost savings.

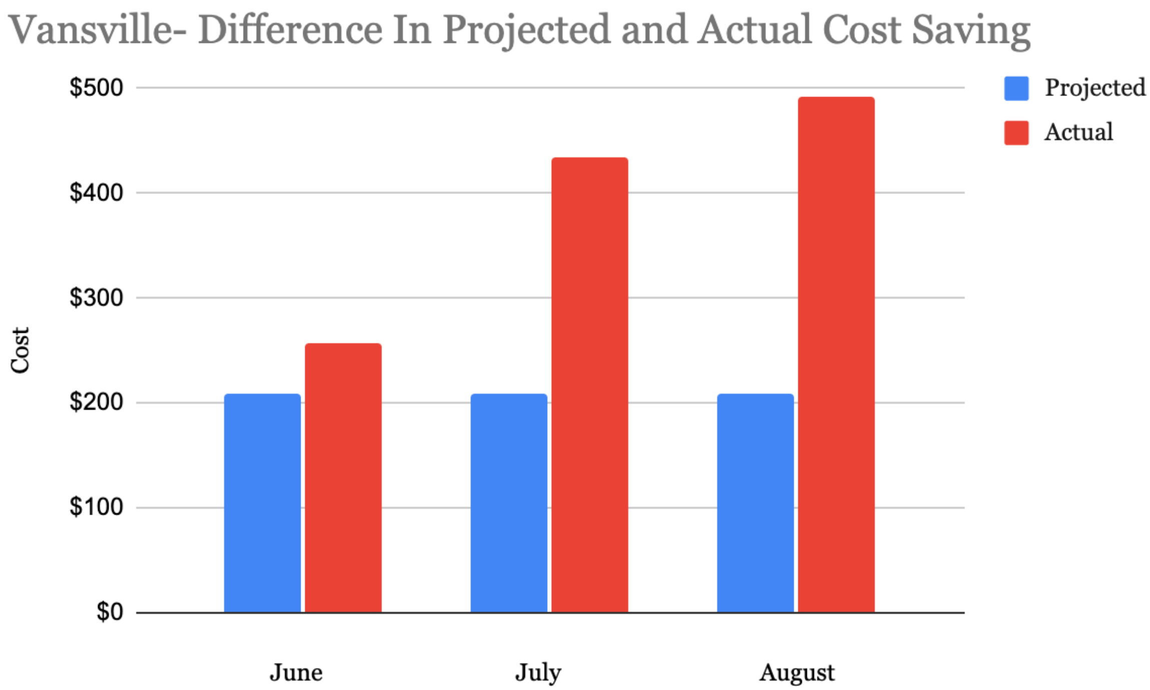

Figure 2
Vansville projected and actual cost savings

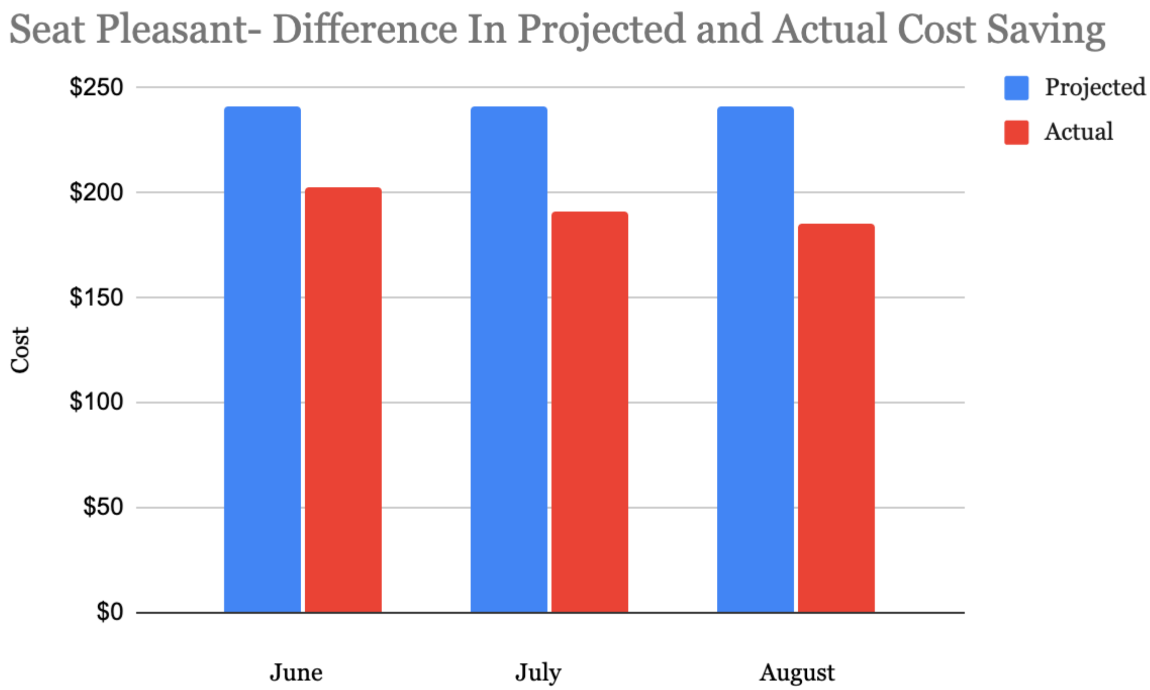

Figure 3
Seat Pleasant projected and actual cost savings

Objective 3: Carbon Footprint Reduction

Carbon Reduction
Using data from 2019 and 2021 summer energy bills and the consultant data, it was determined that lighting accounts for a smaller portion of total daily electricity usage than other sources in each facility, and therefore less total daily carbon emissions than other sources, as determined by the EPA's Maryland emissions factor (Figure 4).

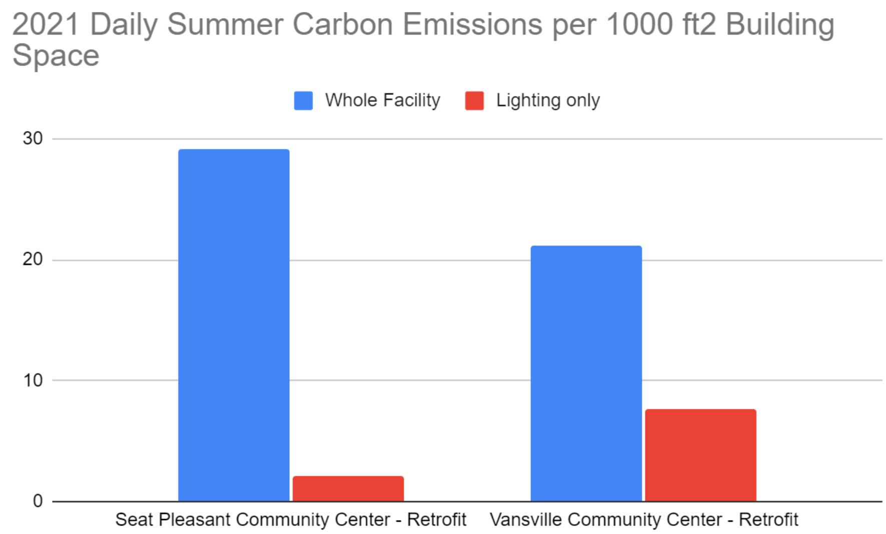

Figure 4
Daily summer carbon emissions—2021

This was especially notable at Seat Pleasant, but lighting was also responsible for less than half of Vansville's total daily emissions per 1000 square feet of building space. Between 2019 to 2021, changes in weather patterns and usage (which was affected by the COVID-19 pandemic) resulted in a decline in daily summer electricity usage and carbon emissions in all facilities, even for non-retrofitted facilities, which experienced an average daily reduction of approximately 11 lbs. of CO_2 per 1000 square feet (Figure 5).

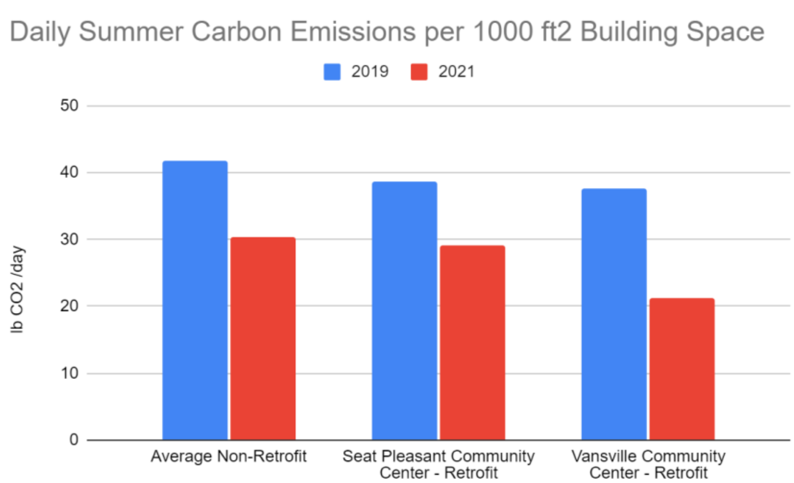

Figure 5
Daily summer carbon emissions

Retrofitting facilities with LED lighting always resulted in lower electricity usage and carbon emissions, but the magnitude of this effect varied depending on the share of total emissions from lighting. At Seat Pleasant, where lighting only accounted for about 6% of total daily emissions, the total daily carbon emissions per 1000 square feet declined by approximately 9 lbs. CO2. However, at Vansville, where lighting accounted for about 33% of total daily emissions, the total daily carbon emissions per 1000 square feet declined by approximately 16 lbs. CO2, a nearly 45% reduction (Figure 5). Seat Pleasant is 18,200 square feet, which shows that retrofits can result in a drastic reduction in carbon emissions, most notably in facilities where lighting makes up a larger portion of total electricity usage.

Temperature

One might worry that the difference in summer weather between 2019 and 2021 could confound the results. If it was significantly hotter or colder in either year, then the amount of electricity used for heating or cooling could skew the results. However, as shown in Figure 6, the weather for the studied months didn't change significantly; . the average monthly temperature differences didn't exceed 1° F.

Further, using the change in energy usage at two non-retrofitted facilities can account for any changes in temperature, occupancy, or other variables. Since the non-retrofitted facilities were also in Prince George's County and subject to the same state and county restrictions on

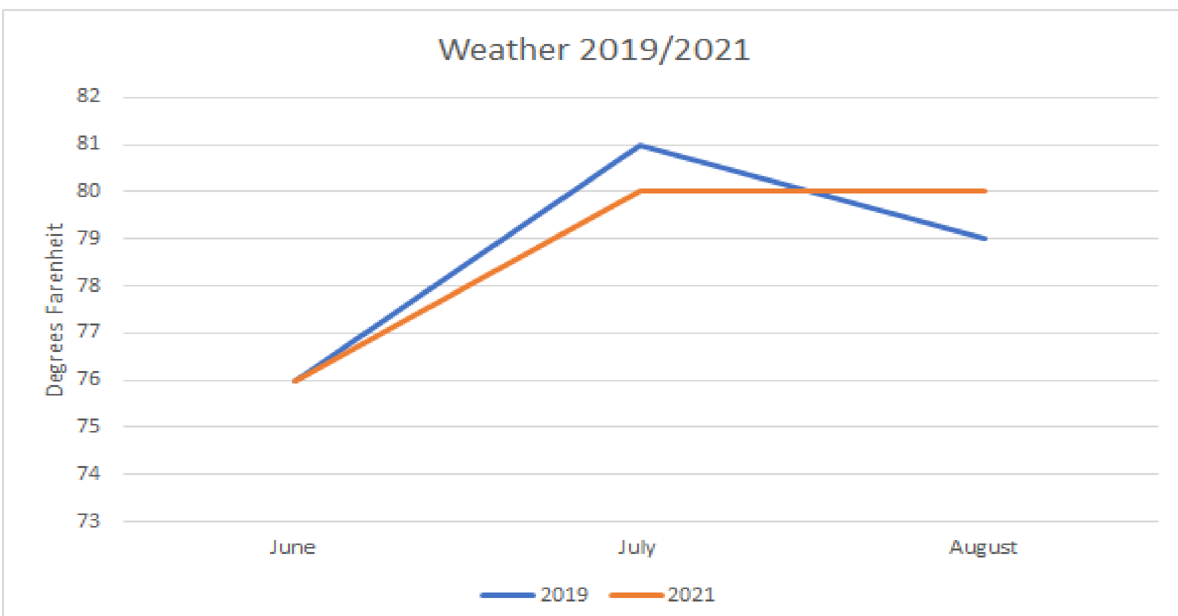

Figure 6
Average temperatures June/July/August 2019 and 2021 from Timanddate.com

occupancy and experienced the same general temperatures, the change in electricity usage at these facilities should account for those variables. With respect to occupancy, a visit to Palmer Park revealed that each community center operates with different hours, summer camps, or other programs. So, occupancy changes are not accounted for as are weather changes.

Literature review of LED carbon costs

There are five stages of life cycle assessment to consider:
1) raw materials extraction
2) manufacturing and processing
3) transportation
4) use
5) disposal.

This review examines the use and disposal stages of LED lights.

The goal of this literature review is to further document the potential carbon and energy savings of switching from fluorescent and incandescent lighting to LEDs. According to one study, "the main environmental benefits of LEDs compared to conventional light sources are low carbon dioxide emission (Nardelli, 2016). LED lights have higher luminous efficacy, that is, the ratio of power to the perceived light. This means that "the intensity per watt provided by LED lamps is lower as compared to other lamps" (Sangwan et al. 2014). LED are popular because they require less energy to create adequate lighting.

In a 2014 study, the manufacturing and processing phase of LED lights was found to be more carbon intensive than Compact Fluorescent Lights (CFL) lights by nearly 70% (Principi, 2014). This same study found that LED lights had a roughly 10% higher carbon impact in their production phase due to several measurable categories: photochemical ozone formation, terrestrial eutrophication, and marine eutrophication (Principi, 2014). LED lights also have a 5% higher carbon impact due to land use during the manufacturing phase, and a 5% higher impact from cumulative energy demand (Principi, 2014).

However, these drawbacks are offset entirely or are of limited significance due to LEDs' benefits in the use stage; most of the decrease in environmental impact from LED lighting comes in the use stage. The same 2014 study reports that, compared to CFLs, there was a "41% reduction in Global Warming Impact of switching to LED lights, with between 96% to 98% of the realized carbon savings occurring during the use stage" (Principi, 2014). In every category measured, LED lights have a lower environmental impact than CFLs throughout their total life cycle. The positive results come from the lifespan of LED lights, which help them realize comparatively high energy reduction and carbon emissions reductions compared to other light sources.

A 2017 study found a similar result. In the manufacturing and processing phases, LEDs were found to have a higher carbon impact than other lights due to the materials used and the methods of production (Franz, 2017). However, the study also found that “LED lights with luminous efficacy of greater than 134 had a much less significant impact on carbon emissions” (Franz, 2017). Luminous efficacy is the measure of how effective a light source is at producing light. Therefore, during the use phase, an LED light with a higher luminous efficacy will use less power to emit the same visible light compared to LEDs with lower luminous efficacy, and to traditional light sources such as CFLs and incandescent lights (Franz, 2017). Comparing LEDs to all other commonly used lighting products found, “LED-lamps have the lowest environmental impact of all lamp technologies for a luminous efficacy > 104 lm/W” (Franz, 2017).

A study of the effectiveness of LED lighting illumination control, where the power generated by an LED fixture can be controlled and adjusted, it was found that LED lights can still create comfortable lighting while using 10% less energy than without lighting control. These energy savings can increase with the use of motion sensors (Liu et al. 2016).

Further down the line, a study comparing LED and CFL products estimates that the disposal stage “represents 0.1-4% of total impact” (Principi, 2014). Another study estimates that, “the environmental impact of waste disposal ranges from negligible to 27% of the total impact (Franz, 2017). A 2016 study found that “LEDs provide an easier recycling procedure that is less harmful than other technologies, which mitigates environmental degradation (Nardelli, 2016). Overall, there isn’t a lot of available data to properly estimate the environmental impact of LED lights in the disposal stage. In the United States, LED lights are hazardous waste, and must be disposed of at specified facilities; LEDs can’t be commingled with regular trash. Internationally, LED lights are disposed of similarly in the EU and some parts of Asia.

While the production phase of LED lights is often found to have higher carbon impacts and energy demands than compared lighting products, they perform much better in every category of energy use and carbon emission than traditional lighting products. LED lights are the least impactful on energy demands and carbon pollution compared to all other lighting products.

To maximize energy savings and minimize environmental impact, the lifetime hours of LED lights should be maximized. LED lights with a high luminous efficacy should be used along with lighting dimmer controls and motion sensors.

VI. Recommendations and Conclusions

Based on these results and findings, the Prince George's County Department of Parks and Recreation should make a complete switch to LED lights and other energy saving devices in all facilities under their administrative supervision, budget permitting.

There is limited quantitative data to back this decision. Because the study examined only two retrofitted facilities for three months of the year, it is hard to determine what could be expected for the average community center. However, the data shows a projected reduction in cost and energy for facilities that have been retrofitted with LED lights. Furthermore, the data also reveals that the cost and energy savings are directly linked to the amount of electricity that is used to light each facility. Facilities that use more electricity for lights will see a greater cost and energy impact.

The predicted overall reduction in energy usage and cost savings directly addresses the client's aims to reduce energy usage and improve cost savings, with the added benefits of reducing the carbon footprint of their facilities.

It is also important to keep in mind that this life cycle analysis further indicates that a switch to LEDs could help the county could save on its energy usage and cost savings and would positively impact the environment as a whole. Retrofitting facilities with LED lights will always result in lower electricity usage and carbon emissions, allowing the Department of Parks and Recreations to further meet their mission of encouraging a healthy lifestyle while providing enriching leisure services.

It is also recommended that all new Parks and Recreation facilities be fitted with LED lights from the beginning of construction. This will be a long-term savings in energy usage maintenance.

In conclusion, we believe that identifying the proper facilities in objective one allowed an examination of the projected and actual cost and energy savings at these facilities from a conversion to LED lighting. This in turn helped determine the realized and potential carbon footprint reduction, which also results from using LED lights. More quantitative data would ensure these results are not skewed based on the small sample size and data.

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VIII. Appendix

Appendix A: Base Case and Findings Math

Link to Spreadsheet:
Updated Weather and Utility Data https://docs.google.com/spreadsheets/d/1nvsa7tA5-lXp6hhNQEKCRKC_W6dedmlpAVXCtJkzMhA/edit#gid=1941487436

Appendix B: Consulting Data

Link to Consulting Firm Document:
https://drive.google.com/file/d/1dhjJwFGBny-EYk2t343AISN1m70cEyI1/view?usp=sharing