Feasibility of Implementing Microgrid Solar Powered Streetlights on UIUC Campus

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Milestone #3 – Final Report

CEE190

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Executive Summary

This is a feasibility study on implementing microgrid solar powered streetlights on the portion of Gregory Drive that is East of South Sixth Street. The Illinois Climate Action Plan (iCAP) has a goal of implementing sustainable infrastructure on campus to reduce the university's environmental impact. Already, iCAP has recognized the potential that improving the sustainability of streetlights on campus can have to meet this goal and has updated the bulbs of these lights from metal-halide to LEDs. To take this concept further, and to help reduce the $100 million that the university spends on energy each year, our team investigated the feasibility of adding solar panels to these LED streetlights. Because one of the possible pitfalls of this plan is certain lights getting more sun exposure than others, we included a system where excess power generated from one solar panel could be used to power another. This system is more commonly known as a "microgrid". We scaled our results from this small feasibility study to all university-owned streetlights to determine if this could be an attractive action for the university to take. We conducted this study by collecting data on the expected sun exposure for the panels, cost of electricity in Illinois, talking to stakeholders and determining optimum components for the system. Our results from comparing similar projects' engineer's estimates and scaling them to the size of our study show that the cost to install the system in the specified area would be around $18,000. Our cost savings estimate shows that this system would save the university nearly $1,000 a year. From energy consumption data, we found that the average yearly CO2 emissions from the 37 lights in this study would be around 1,300 kg which is a reduction of around 3,400 kg per year from the current system in place. Considering this, we can conclude that implementing these solar streetlights and connecting them through a microgrid is both an economically and environmentally sound decision. It is our recommendation that the University of Illinois at Urbana Champaign pursue this project.

Introduction

Currently, the University of Illinois at Urbana Champaign (UIUC) is exploring ways to implement sustainable infrastructure on campus. This initiative is spearheaded by the Illinois Climate Action Plan (iCAP). Last year alone, UIUC used more than 3.2 quadrillion joules of energy (iCAP Sustainability 2021) and iCAP is actively finding ways to reduce this number as well as find cleaner energy sources to minimize environmental impact. Additionally, UIUC spends $100 million a year on energy (Illinois Facilities and Services 2021). If this large amount were to be reduced, the university could reallocate funds in ways that would benefit the students more directly (i.e., reduced tuition, free textbooks, etc.)

In making progress towards their sustainability goals, iCAP recognizes the importance of implementing light fixtures that consume a minimal amount of energy and has worked to upgrade all exterior lights (including streetlights) from metal halide to LEDs (iCAP Sustainability 2021). This action reduced the university's total energy consumption and saved money.

Although this is a step in the right direction to achieve the goals outlined above, this concept can be taken further. With the intention to reduce the costs of electricity from exterior lights and simultaneously work towards iCAP's sustainability goals, our team plans to investigate the feasibility of converting LED streetlights to run on solar energy and to be connected through a microgrid. For the purposes of this study, we will limit our range to the 37 streetlights on Gregory Drive East of South Sixth Street, as highlighted in Figure 1. After this investigation, we will scale our results to a university-wide level, to determine if its implementation would be practical on a larger scale.

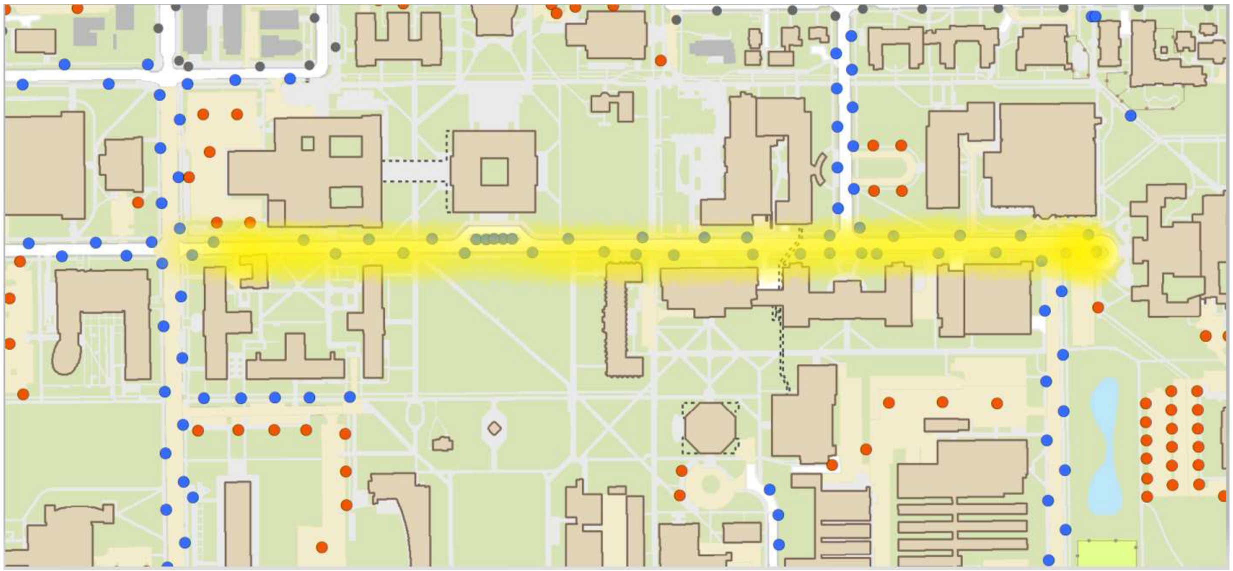

Figure 1: This figure shows the lights that we have included in our feasibility study (highlighted) (iCAP Sustainability 2017).

In the long run, the use of Solar Powered LED Lights would decrease the amount the university spends on exterior lighting, in addition to reducing UIUC's carbon output. Compared to the traditional metal halide streetlights, our proposed lights would reduce the wattage needed by a factor of six, eliminate some energy costs, and simultaneously reduce the need to rely on natural gas and fossil fuels to provide electricity for streetlights (HeiSolar 2021).

A study conducted in Alexandria, Egypt found that the use of solar energy through "smart streetlights" (see Figure 2), rather than traditional "on-grid" energy consuming streetlights, reduced the overall electricity consumption of the province by 30 percent while reducing electricity consumption costs by 50 percent (Abdelhamid 2020). This study discovered the positive impacts of using solar panels on streetlights and public buildings. This study is similar to what we are attempting to find: the feasibility of implementing solar streetlights on the UIUC campus. We can infer that the success of this project overseas is possible to duplicate on a smaller scale here at the university.

Figure 2: Example of smart streetlight (AGCLED 2021).

A similar project was recently conducted in the city of Beaumont, California. In 2015, the city decided to be the first in the nation to install solar powered fixtures for all new streets and parking lots. The installation of these fixtures resulted in eliminating electricity consumption costs from the streetlights (FirstLight Technologies 2018). This is a promising solution to reducing electricity consumption on the UIUC campus because it reduces the need for electricity coming from the grid to power the proposed streetlights.

Our proposed solution involves attaching solar panels to existing streetlight structures on Gregory Drive. One potential factor we recognize could negatively impact the feasibility of this project is fluctuating sun exposure, particularly in shady areas. Additionally, there is not significant sun exposure every day of the year. Measurements from the Illinois State Climatologist website for Central Illinois show there was an annual average of 95 clear days, 97 partly clear days, and 173 days with overcast (Illinois State Climatologist 2021). To lessen this effect, we will keep the streetlights connected to each other through a microgrid; each light would be able to power another through a connected circuit. This would also help if one light is placed in a shaded area as another light placed in a clear location would be able to help power it. The microgrid system proposed would consist of solar panels located on the newly installed streetlights, a solar charge controller, and a DC-AC power inverter. The microgrid will be connected through a subterranean electrical circuit installed by direct burial.

There are other possible solutions including the replacement of bulbs with even more energy efficient LEDs than those in current use, which will help reduce electricity consumption. However, this proposition will not have the same magnitude of impact that our solution has: greater reduced carbon emissions and less reliance on nonrenewable sources to power UIUC's campus. Another possible solution would be not turning on the streetlights at all. This would reduce UIUC's carbon impact by more than our proposed system would (as eliminating streetlights also eliminates their carbon output). Despite the larger decrease in CO2 emissions, this solution will eliminate the purpose of having streetlights in the first place and be a safety concern, therefore it is not a viable solution in comparison to our proposed solution. In conjunction with our proposed project, a different possible solution would be creating a microgrid with solar panels located on roofs of university-owned buildings that would be used to power the streetlights. This solution would take up more space than our proposed plan and would likely require reinforcement of university roofing. However, this solution would have the capability to produce more energy, the panels would be larger than the size of the ones used for our streetlights.

Objectives

Our team will determine the feasibility of converting current LED streetlights on Gregory Drive to be microgrid connected and solar powered. The implementation of this project may be financially beneficial for the university as it could provide a renewable and low-cost energy source, therefore decreasing electric utility expenses in the long run. Additionally, UIUC's iCAP program is attempting to move towards a more self-sustaining, carbon-neutral campus within the next 30 years or sooner. Presently, most lights on the university campus consume nonrenewable electricity and are not helping to achieve iCAP's objectives. To assess if this option would help iCAP meet its goals and save the university money, we will collect data on current codes, stakeholders' interests, and optimum components for the streetlights. Based on these components, we will calculate the expected reduction in energy costs to the university. Then we will investigate possible environmental impacts by calculating the effect on carbon dioxide emissions that this system would have. We will produce a parametric cost estimate for this project, calculate expected savings and create a report on our findings. After these steps have been completed, we will scale our results to entire streetlight system owned by the university to determine whether the school should consider applying this change to all their streetlights. We will present this report to the universitie's department of Facilities and Services, specifically Shop 25 which manages the university's streetlights, and the Student Sustainability Committee (SSC) so that they can determine if this would be a practical project for the university to take on. This feasibility study took nine weeks as expected and detailed in the methodology.

Methodology

Over a 9-week period, our team determined the feasibility of converting current streetlights on Gregory Drive East of South Sixth Street to solar-powered LED streetlights connected through a microgrid. The study began with collecting data and interviewing stakeholders. Next, we investigated the environmental impacts of converting lights to solar power by contacting local officials, as well as processing pollution reduction data for the following two weeks. In tandem, we conducted a parametric cost estimation and investigated the economic benefits of switching to a solar microgrid system. Lastly, we finalized our data and concluded our feasibility study by formatting our findings into a brief but concise 6-minute slideshow and a more in-depth “Request for Proposal” that we can present to the University Student Sustainability Committee and Department of Facilities and Services. It is important to note that we omitted conducting a detailed cost estimation because we felt the parametric estimation was thorough enough.

Data Collection and Interviews

Our team reviewed local codes to determine important details including if we would be allowed by city and state laws to perform our proposed project assuming it is decided upon. Interviews with stakeholders such as Morgan white (ICAP chair member) and Brian Johnson (facilities and services) were conducted to gage interest. A site visit was made to locate challenges like shady spots that may make our project less viable. We reviewed similar systems and made decisions on the components we would use to base our study on.

Environmental Impact investigation

We contacted an influential member of iCAP, Morgan White, to hear her input on the possible environmental impacts related to our feasibility study. Then we conducted a theoretical energy consumption analysis (in watts) for before and after the proposed installation of solar panels on streetlights. With this data we calculated the carbon dioxide output of both the current lights and the proposed lights. Finally, our team determined that the amount of CO2 reduction would be significant enough for this project to be viable.

Conducted a Parametric Cost Estimation

A parametric cost estimation of the study was conducted using engineer’s estimates of similar projects. We found similar projects and scaled their costs to the size of our project. Economic benefits associated with this proposed project were calculated by finding the reduction in energy consumption costs.

Analyzed Data and Produced a Conclusion

Given all our data collected, we formed a conclusion that this study is feasible and a viable solution to help reduce university CO2 production and energy consumption costs. These findings have been formatted in a brief slide show and this document. Both this document and the slideshow are set up in a manner that is presentable to the University Student Sustainability Committee and Department of Facilities and Services.

Results and Discussion

The following section is divided into subsections that include various data we have collected and used in this feasibility study. The sections are Efficiency of Streetlights, Cost Estimate, Cost Savings Estimate, Carbon Dioxide Emissions, our results scaled to the size of the full UIUC campus, and Interest from Stakeholders. Each subsection is in paragraph format with supporting figures and tables. The figure in Appendix 4 shows a comparative summary of key data from the current streetlights versus the proposed streetlights.

Efficiency of Streetlights

According to the Illinois State Climatologist, Central Illinois has an average of 95 clear days, 97 partly clear days and 173 overcast days (Illinois State Climatologist 2021). For the purposes of this study, we will assume both partly clear and clear days will provide sufficient sun to power the solar panels and overcast days will provide insufficient sun. This means that for 173 out of 365 days (or 47.4% of days) our proposed streetlights will be unable to generate power from the sun and therefore must rely on reserves from the power bank in the microgrid or an outside energy source. As shown in Appendix 1, our streetlights will require about an extra 3,330 kWh of energy to maintain year-round function.

Based on our research, we found that the City of Urbana receives an average of 12.2 hours of sunlight a day meaning that the streetlights are on for the other 11.8 hours. Using this number, we find the amount of energy the streetlights will consume per day is 0.8869 kWh while the amount of energy produced per day (when adequate sunlight is available) is 1.2175 kWh. This means that each day, each streetlamp produces an excess of 1.033 kWh that can be stored. We then calculated how much energy the streetlights would consume per year (324 kWh) and compared it to the amount of energy it could produce per year (234 kWh). This situation results in a deficit of 89.9 kWh per streetlight per year that must be supplied by other energy sources. This equates to roughly 3,330 kWh for the 37 streetlights on Gregory Drive as calculated in Appendix 1.

Cost Estimate for Microgrid Solar Streetlights

To estimate the cost of implementing microgrid solar streetlights, we used a parametric cost estimation that was composed of data collected from the engineer’s estimates of other similar projects. The purpose of using this type of cost estimation is to help both the client (the UIUC Student Sustainability Committee and Department of Facilities and Services) and our team determine an accurate estimation of what our proposed project will cost. We chose to find costs of similar projects using engineer’s estimates because they include both the material and labor costs. For this type of parametric estimation, we assume that the materials used in other microgrid solar projects are similar enough to those we will use in our project so that they are comparable. This should provide us with a precise cost estimation as this data was collected from 6 different project estimates and gives us a broad enough scope for confidence in our estimation. Our parametric cost estimation is detailed in Table 1 below. This cost is estimated to be $17,700 for our scale of project.

Table 1: Parametric Estimate (Using Engineer's Estimate Data from other similar projects)

Solar Streetlight Conversion Company and Project they placed a bid on	Total Cost of Project	Quantity of Streetlights in Project	Proposed Quantity of UIUC Streetlights	Scaled cost for UIUC Streetlight Conversion
Affinity LED: All of Saco, ME streetlights conversion project	$564,481	1,582	37	$13,202
Dalkia Energy: Saco, ME Streetlight conversion project	$341,053	1,425	37	$8,855
Affinity LED: Saco, ME streetlight conversion project	$515,447	1,425	37	$13,384
Tanko streetlighting inc.: Saco, ME Streetlight project	$491,686	1,425	37	$12,767
Fred S. Carver Inc.: Adelphi, MD Solar Powered Streetlights	$16,871	15	37	$41,615
North Dakota State University: North Dakota Highway 281	$48,400	108	37	$16,581
			Average Cost:	$17,734

<u>Cost Savings Estimate</u>

After personal correspondence with Brian Johnson, a member of University of Illinois Facilities and Services, our team discovered that the streetlights turn on and off based on feedback from a sensor on top of the Mechanical Engineering Laboratory. When there is no longer sufficient light, the sensor recognizes the absence of light and turns on the campus streetlights. Based on this information and assuming that "sufficient sunlight" is equivalent to "daylight", we were able to calculate the average number of hours a day these streetlights would be on, using data from the 2021 Sun Graph for Urbana (Figure 3). These results are detailed in Table 2 and used in calculations for Appendix 1.

It was observed that the most "light-hours" during the day this year (from sunrise to sunset) was approximately 15 hours. The least number of light hours is predicted to be approximately 9.3 this year. Using these numbers, laid out in Table 2, and the shape of the "2021 Sun Graph for Urbana" (Figure 3) we determined that the average of these two numbers would give us an adequate estimate for the average amount of light hours per day for the year (roughly 12.2 hours) (Time and Date 2021). By subtracting this number from 24 hours a day, it is found that on average, the streetlights are on for 11.8 hours per day. The current LED streetlights are 75 Watt (LED Lighting Supply 2021) and there are 37 streetlights on the area of Gregory Drive being investigated, as seen in Figure 1. The current average price of electricity in Illinois is $0.1116 (Energy Bot 2021). By calculating the product of these numbers, we can conclude that currently the energy spent per year without the microgrid system is roughly $1,300 as shown in Appendix 2. The data used for this calculation is shown in Table 3.

As calculated in Appendix 1, there are roughly 3,330 kWh of energy per year that cannot be produced by the solar panels to meet the needs of the streetlights. Thus, this energy must be produced traditionally and costs $0.1116/kWh to do so. This equates to a cost of about $370 per year. However, since the university currently pays roughly $1,340 to power its streetlights, this equates to a net savings of almost $1,000 as outlined in Appendix 2.

To calculate how long it would take to recover the initial investment (the cost of implementing the system), the cost of implementation (roughly $18,000) is divided by the savings per year (just under $1,000) as detailed in Appendix 3. The result is 18.4 years, meaning that it would take the university this amount of time to make up for the money expended in implementing the microgrid streetlight system.

Table 2: Average Number of Hours of Light during the Day

"Light-hours" during the day	# of Hours
Most (July 20, 2021)	15.0
Least (December 21,2021)	9.3
Average	12.2

Table 3: Data for Cost Savings Estimation

Average time lights are on	Energy Consumed by each Light	Average Price of Electricity in IL	Number of Days in a Year	Number of Streetlights in Study
11.825	0.075 kW	$0.1116/kWh	365	37

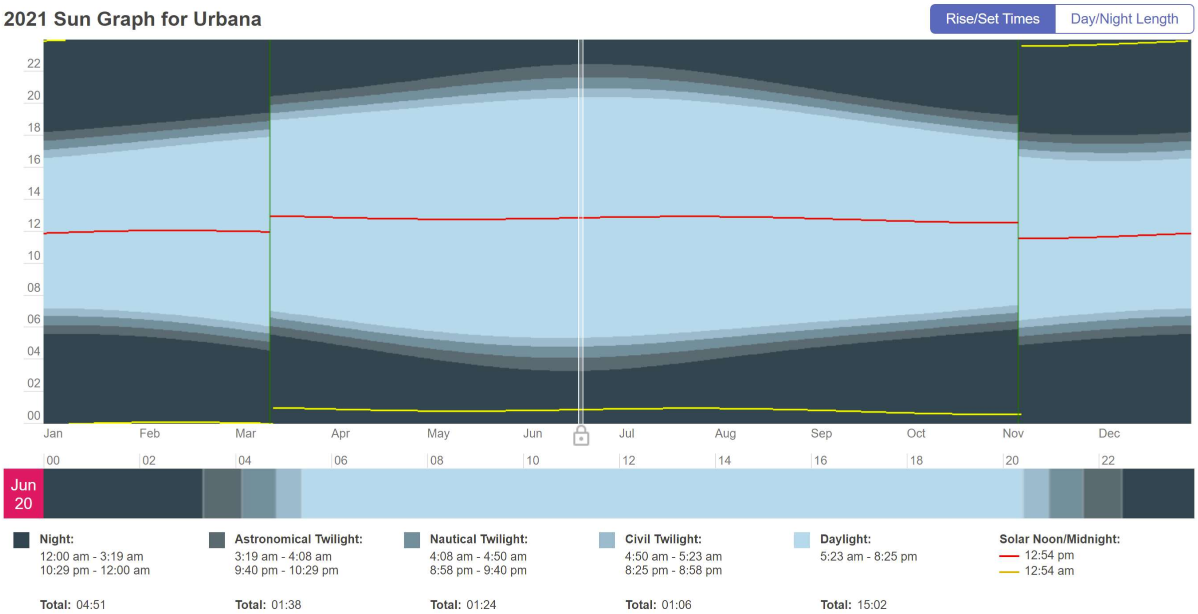

Figure 3: 2021 Sun Graph for Urbana (Time and Date 2021).

<u>Carbon Dioxide Emissions</u>

Electricity production is the highest cause of carbon dioxide and other greenhouse gases on campus, emitting just over 135 million kg (419 thousand tons) of carbon dioxide in 2016 (iCAP 2021). By switching the university's current streetlights to Solar LEDs, carbon emissions from electricity production will decrease. From earlier calculations, current streetlights use just under 0.89 kWH per day, while the proposed streetlights will run under significantly reduced electricity needs and only draw a minimal amount of energy from other sources. Based on carbon dioxide emissions for 2020, the average emissions per kilowatt-hour was 0.39 kg of carbon dioxide (EIA 2021). Multiplying this by the number of streetlights in our study and the amount of electricity (kWh) they consume, the estimated emission from the current lights is 12.8 kg of carbon dioxide per day. By switching to the proposed Solar Microgrid system, the carbon dioxide emitted from the production of electricity for streetlights would be cut to about 3.5 kg per day. This equates to a savings of roughly 3,400 kg (3.7 tons) per year. Results and data are displayed in Table 4.

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Table 4: Carbon dioxide emissions estimate

	Electricity needed per Streetlight per day	Carbon dioxide emissions per kWH (kg)	Number of streetlights in study by university	Total emissions of streetlights (kg)
Current Streetlights	0.8869 kWh	0.39 kg	37	12.798 kg
Proposed Streetlights	0.24644 kWh	0.39 kg	37	3.556 kg
			Daily Emission Reduction	9.242 kg (1.02E-2 tons)
			Yearly Emission Reduction	3,373.33 kg (3.7 tons)

<u>Scaled Results</u>

Using the results from our estimations calculated with 37 streetlights (which can be seen in comparison to current streetlights in Appendix 4), we scale our data to a university-wide level (as shown in Table 5). Currently, the university owns 1,509 streets and parking lot lights (iCAP 2021). Our scaled calculations, as outlined in Table 5 show that the cost of implementing this system for the entire university would be around $700,000. It would save the university $40,000 a year in energy costs and would reduce their carbon dioxide emissions by 138,000 kg. Like the 37-streetlight system, this larger system would also take 18.4 years to repay the initial investment. This is because the ratio of cost of implementation to savings per year is the same for the university-wide system as it is for the Gregory Drive system.

It is important to note that our figures for cost savings per year and carbon dioxide emission reduction may be slightly less in actuality than calculated. None of the 37 streetlights we studied were positioned such that they could not receive sufficient sunlight. As this may not be the case for all the 1,509 streetlights on campus, the figures may be slightly overestimated. However, based on our observations of Gregory Drive, it is unlikely that enough lights on campus would be in places without adequate sunlight to make significant differences in these calculations.

Table 5: Scaled Cost Estimations

	Cost of System	Cost Savings Estimate (per year)	Time Needed to Recover Initial Investment (years)	Carbon Dioxide Emission Reduction per Year (kg)
For 37 Streetlights (Gregory Dr)	$17,734	$965.24	18.4	3,373.33
For 1509 Streetlights (Entire University)	$723,260	$39,366.14	18.4	137,577.16

Interest in Project from Stakeholders

After personal correspondence with Morgan White, iCAP liaison and Facilities & Services Director for Sustainability at the University of Illinois at Urbana Champaign, it was clear that iCAP and the Institute for Sustainability, Energy and the Environment (iSEE) would be interested in this type of project. She thought that the Student Sustainability Committee (SSC), a group within iSEE, would be interested in supporting this project. She believes our project reflects iCAP's goals of reducing campus emissions and asked our team if we would be interested in working with the SCC to request funding for the project in the spring.

Conclusions

Microgrid-connected solar streetlights are an effective solution to reducing CO2 pollution while minimizing electricity consumption costs for the University of Illinois. The University of Illinois Facilities and Services estimate that nearly 100 million dollars are being spent on university electricity consumption per year. On top of that, much of the energy being used is produced through nonrenewable practices such as the burning of fossil fuels. UIUC's iCAP program is attempting to move towards a more self-sustaining, carbon-neutral campus within the next 30 years or sooner by reducing CO2 pollution and reliance on nonrenewable energy. Our objective was to determine the feasibility of converting current LED streetlights on Gregory Drive to be microgrid connected and solar powered. Within our objective we were looking to find how much money the university could potentially save from the implementation of these lights, how much pollution could be reduced, and how much it may cost to implement. After conducting our research, we have found that this solution has proved to be a viable option for UIUC to pursue as it would pay for itself through its yearly savings in about 18 years, reduce CO2 emissions, and be an economical project to implement. After the break-even timeframe has been completed, the project will then save the university approximately $1000 dollars a year in electrical expenses. Because these lights need only a minimal amount of electricity from the grid, they will reduce CO2 pollution that is caused from the production of electricity. Along with those benefits, we estimate that the cost of implementation will only be around $18,000 which is very reasonable in comparison to other "environmentally friendly systems". We acknowledge that a limitation of these lights might be lack of adequate sunlight in certain areas. Through research, it was determined that this limitation can be reduced if the lights are interconnected through a microgrid system, which makes this project more viable than stand-alone solar lights. Overall, converting the current streetlights to microgrid solar powered LED lights would be economically and environmentally beneficial for the university. Along with the incentive to reduce electricity expenses and CO2 emissions, this project has proven to be feasible. The results of this study may nudge the university towards a decision of implementing these lights not only on the specified street in our study but perhaps for all the university owned streetlights.

Acknowledgments

Morgan White

Morgan White helped us with a key part of determining the feasibility of the project by providing us with insight into stakeholder interest, specifically from iCAP, Institute for Sustainability, Energy and the Environment (iSEE) and the SSC. She also connected us with a member of the SCC to discuss applying for funding to implement this project in the spring.

Brian Johnson

Brian Johnson is a member of Shop 25, a division of Illinois Facilities and Services that controls the UIUC streetlights. He explained to us how and when the streetlights turn on, and how a photo eye on top of the Mechanical Engineering Lab (MEL) senses when it is dark enough to turn on.

Disclaimer

This report was produced for academic purposes only by undergraduate students at the University of Illinois at Urbana Champaign and is not intended for professional use. These recommendations may be based on insufficient data and information.

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Appendix

$$24\ hours - 12.175\ hours\ of\ light = 11.825\ hours\ in\ use$$

$$Energy\ Consumed/day: 11.825\ h * 0.075\ kW = 0.8869\ kWh$$

$$Energy\ Produced/day\ (when\ adequate\ sun): 12.175\ h * 0.1\ kW = 1.2175\ kWh$$

$$Excess\ Energy/day: 1.12175\ kWh\ (when\ adequate\ sun) - 0.8869\ kWh = 1.033\ kWh$$

$$Energy\ Consumed/year: 0.8869\ kWh(per\ day) * 365\ days = 323.71\ kWh$$

$$Energy\ Produced/year: 1.2175\ kWh(per\ day) * 192(full\ \&\ partial\ sun\ days) = 233.76\ kWh$$

$$Deficit\ Energy\ per\ light: 323.71\ kWh - 233.76\ kWh = 89.95\ kWh$$

$$Deficit\ Energy\ Total: 89.95\ kWh * 37(lights) = 3{,}328.15\ kWh$$

Appendix 1: Calculations used to find Energy consumption and Extra energy needed

$$0.075\ kW * 11.825\ h = 0.8869\ kWh\ (energy\ consumption\ per\ light\ per\ day)$$

$$0.8869\ kWh * \$0.1116 = \$0.0990\ (price\ of\ electricity\ used\ per\ light\ per\ day\ per\ light)$$

$$\$0.0990 * 356\ days * 37\ streetlights = \$1336.66\ (yearly\ cost\ to\ operate\ without\ solar\ system)$$

$$3328.15\ kWh * \$0.1116 = \$371.42\ (cost\ of\ energy\ unable\ to\ be\ produced\ by\ solar\ system)$$

$$\$1336.66 - \$371.42 = \$965.24\ savings\ per\ year$$

Appendix 2: Cost Savings Calculations

$$\frac{\$17{,}734\ (cost\ of\ implemention)}{\$965.24\ (savings\ per\ year)} = 18.4\ years$$

Appendix 3: Time Needed to Recover Initial Investment

Evaluation Criteria	Current Streetlights (37 units)	Proposed Streetlights (37 units)
CO_2 Pollution (kg) per year	4,700 kg	1,300 kg
Energy Consumption (kWh) per year	12,000 kWh	3,300 kWh
Cost (dollars) per year	$1,300	$370
Cost (dollars) to implement	$0 (already in place)	$18,000

Appendix 4: Comparative Summary of current streetlights versus proposed streetlights

Group Reflections

Overall, this project was a success. In determining the feasibility of microgrid solar streetlights, our team made a few key decisions. The first was to use a parametric engineers estimate rather than a bottom-up estimate because our team did not have the expertise to know every part that was needed for this type of project. By scaling these estimates to price per streetlight and then scaling up to the number of streetlights we had, 37, we were able to accurately estimate how much this project would cost, without having to completely understand how the system operated. Another key decision we made was to disregard the role shaded areas would play in our cost savings estimation. After observing that all streetlights on Gregory Drive received adequate sunlight most hours of the day, we concluded that it was unlikely enough streetlights are shaded on campus (cannot receive adequate sunlight) to make a significant difference in our cost estimation. Additionally, we chose to study university owned streetlights only, rather than the City of Urbana or Champaign owned streetlights which intermix with university owned streetlights some places on campus. This was done so that we wouldn't have to account for differences in city codes and possible legal issues during our estimations.

There were some errors we made in the process of developing this report as well as things we could have done differently, which mainly surrounded the principle of accuracy of data. For example, our use of an engineer's estimate compensated for the fact our team did not fully understand the workings of the solar streetlight system. However, this could be problematic if the campus had some difference that prevented streetlights from being installed in the usual way (ie. codes, cement makeup, waterlines etc.) The fact that our team disregarded shade almost entirely could also be a threat to the integrity of this report. By failing to conduct an entire campus site survey, we may have ignored parts of campus that, by design, have many shaded streetlights and therefore could not receive sufficient sun. This would have a significant impact on our data. Regarding the prediction of sun exposure, we could have taken better data. We based our conclusions off terms such as "sufficient sunlight", "light hours" and "dark hours" without defining them precisely. Additionally, we did not fully investigate the role seasons played regarding sun exposure in our report. For example, it is possible that a streetlight could receive insufficient sun in the spring and summer when it is shaded by leaves from a tree, but in the fall and winter (when those leaves fall) it could receive sufficient sun. Another important factor disregarded was the lifespan of the panels. We did not consider the economic and environmental costs of replacing them and maintaining them. To obtain better data, we could have taken these factors into account.

As civil engineering students, this project was an extremely valuable experience. Our team gained a great deal of technical knowledge about microgrid solar streetlamps and the University's lighting system. For example, we now understand how UIUC's streetlamps operate (their types of bulbs they use, how they turn on, how many there are etc.) and work that has been done by iCAP in the past to improve their sustainability. Our team was also able to develop basic engineering skills that will benefit us greatly moving forward with our educations, internships and future careers. These included working with teams, conversing with stakeholders, determining feasibility and writing technical reports.