Solar Viability in the Historic District of Worthington

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Executive Summary

In order to help Worthington become a more sustainable city, our group explored the viability of solar and other energy saving mechanisms in the Historic District of Worthington. The main objectives for this project were to investigate the economic feasibility of a large scale solar project and a small scale solar project. Additionally, we researched low-cost, energy saving improvements that could be implemented into existing historic buildings. In researching these objectives, we emphasized maintenance of the historic character of the buildings.

A large-scale solar project on the roof of Old Masonic Lodge was evaluated using three funding alternatives: a PPA, a solar loan, and an up-front capital investment. None of these alternatives proved to be economically viable. Next, we focused on our second objective of a small-scale solar project. Solar LED streetlights were identified as a potential cost-effective small-scale solar project. The payback period for this would be 4.388 years, with a 20.59% annual return on cash flow. In order to create energy savings in historic buildings, Kilbourne Memorial Library was selected as a model building. Improvements to lighting efficiency, water efficiency, and air filtration were explored.

Our group recommends that Worthington does not invest in a large-scale solar project at this time. However, we do recommend that they install solar street lights because of their economic and environmental benefits to the community. To improve the energy efficiency of Worthington Kilbourne Library and the rest of the buildings in the historic district, we suggest replacing all the light bulbs with LED bulbs, adding faucet aerators to the sinks in the bathrooms, and weather stripping the windows.

Section 1: Introduction

Worthington is a growing suburb of around 14,000 residents who take pride in their town’s distinct character, and especially in the Historic District. The overall goal of this project was to analyze the potential for solar power within this area. Our research focuses on the financial and logistical viability of large and small-scale solar power in this district as well as energy saving techniques that can be integrated into the renovation of historic buildings.

The City of Worthington originally assigned this task to us and the high level of resident interest motivated our research. Worthington residents are interested in protecting the livelihoods of future generations through sustainable practices such as solar power. This can be seen through the efforts to form a solar co-op as well as the high participation in the “Sustainable Worthington” organization. The solar co-op, managed by OH-SUN currently has 71 participants, but is expected to grow to over 100 within the next few months. According to Sustainable Cities Collective, suburbs like Worthington have the potential to lead the way for sustainable development due to their high level of social capital and middle-class socioeconomic status. Comparable Ohio cities such as Oberlin and Upper Arlington are already taking great strides towards solar power investment and Worthington should seize the opportunity to join them.

Our results found that the large-scale solar project, a 48 kW system on the top of Old Masonic Lodge, is not a financially viable option at this time. However, the smaller scale project, converting 100 street lights to solar LED streetlights, is a beneficial investment. In addition to these results, we found that LED lights, weather stripping windows, and adding faucet aerators to sinks would save energy in the buildings from the Historic District without compromising their historic character.

Section 2: Objective 1 Large-Scale Solar

2.1: Methods

In order to determine the viability of large-scale solar within the City of Worthington's historic district we looked at the cost and benefits associated with three distinct financing structures: Power Purchase Agreement (PPA), solar loans, and full upfront capital investment. The first financing structure assessed in this report is the power purchasing agreement model. In this model, the city of Worthington would allow a third-party provider to install an array, and thereafter the building's residents would purchase all of their power at an agreed upon PPA rate. The second financing structure assessed the benefits of self-generation with financing from a solar loan, more commonly known as a home equity line of credit. Most solar loans have interest rates ranging between 3.5 to 4.5% annual percentage rate (APR). This solar financing method proved to be better than PPA agreements in that the owner of the system would receive all Renewable Energy Credits, and incentives, which could be sold into a Renewable Energy Credit marketplace. This likely reduces the payback period of the installation. The third financing structure is a full upfront capital investment, meaning Worthington would pay for the solar system upfront and hope that after many years of service the system would pay for itself.

Currently, solar projects are eligible for 30% federal investment tax credits. This allows for the municipality or owner of the complex to receive tax credit for 30% of the capital cost of solar generation equipment. The State of Ohio has also provided the incentive of state tax-free investments in renewable energy technologies. In determining the overall return on investment for a solar array, we looked at Renewable Energy Credits, Net-metering policies, and estimated yearly power production figures. These were used to calculate the value of energy produced on an annual basis versus simply purchasing power directly from the utility for 25 years.

In order to estimate the annual costs and benefits per annum of implementing solar we included the cost of operation and maintenance, PPA rate pricing per kWh, average escalator rate, and the estimated power production based upon historical data for yearly insolation averages in the city of Worthington. The yearly reduction in power production due to solar panel degradation was also taken into account. These variables helped us identify which financing alternative presented the highest net-benefit.

2.2: Results

For the large-scale solar project, various buildings were assessed based on optimal positioning, an unobstructed south-facing roof, and the need for power. Additionally, the location could not hinder the city of Worthington's building code and historic aesthetics. We determined the Old Masonic Lodge met these conditions.

Our first financing model assessed was the PPA contract, which on average consists of a 15 to 25 year commitment locking in fixed PPA electricity rates for the duration of the contract and rising at a specified escalator rate. The upfront cost of the panels, installation, and grid-tie configuration as well as the soft-costs like permitting and inspections, are covered by the third-party provider. In addition, the third provider purchases the remaining electricity needed to cover all of the customer's requirements. Table 1 (Appendix) examines the 25 year costs associated with financing a solar generation system using this financing method with a PPA escalator rate of 2.5%.

The main issue with this type of solar funding is that the third-party provider must create returns for its shareholders and cover its costs of capital as well as take on the price risks of procuring electricity over a long time period. Therefore, while the PPA rate they charge for the first few years may be only somewhat above local utility pricing, the solar PPA rate structure actually begins to increase substantially above projected local utility rates thereafter. This price increase is due to the escalator rate of the PPA agreement (2.5%) and varies significantly between providers and states. This escalator rate makes the cost of solar about 3.5 cents higher per kWh after 8 years compared to simply purchasing power from the utility. We also assumed that the local utility rate would rise at 2% per year, or roughly at the expected inflation rate and consistent with past increases. Figure 1 shows the various 25-year cost projections of implementing the various financing structures discussed above vs. simply continuing business as usual and continuing to purchase power from AEP of Ohio.

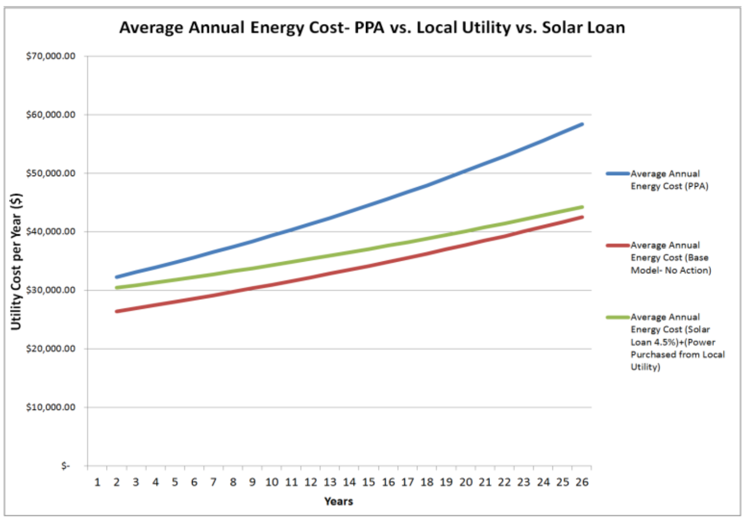

Figure 1: *Average Annual Energy Cost*

Table 2 illustrates that purchasing a 48 kW solar array using a PPA financing model would cost $10,275.12 more annually than no action. Using a solar loan to purchase this system, would require $2,938.31 more annually than energy costs would be without the system. Moreover, we determined that a solar array installation would not be economical because continuing to purchase power directly from the local utility would be cheaper than investing in a solar power generation system. While this is the current conclusion for Historic Worthington, we believe, as solar costs continue to plummet solar will become a viable option in the near future.

Table 2: Cost Benefit Analysis for Masonic Lodge Solar Project

Masonic Lodge 48 kW System Running Cost				
Estimated AEP Power Price (2% Annual Increase $/kWh)	*Average Annual Energy Cost (PPA)*	*Average Annual Energy Cost (Solar Loan 4.5%)+(Power Purchased from Local Utility)*	*Average Annual Energy Cost (Base Model- No Action)*	*Year*
Annual Assumed kWh Usage=293,700kWh				0
0.09	$ 32,307.00	$ 30,442.41	$ 26,433.00	1
0.09	$ 33,114.68	$ 30,891.67	$ 26,961.66	2
0.09	$ 33,942.54	$ 31,350.33	$ 27,500.89	3
0.10	$ 34,791.11	$ 31,818.56	$ 28,050.91	4
0.10	$ 35,660.88	$ 32,296.58	$ 28,611.93	5
0.10	$ 36,552.41	$ 32,784.59	$ 29,184.17	6
0.10	$ 37,466.22	$ 33,282.78	$ 29,767.85	7
0.10	$ 38,402.87	$ 33,791.37	$ 30,363.21	8
0.11	$ 39,362.94	$ 34,310.58	$ 30,970.47	9
0.11	$ 40,347.02	$ 34,840.62	$ 31,589.88	10
0.11	$ 41,355.69	$ 35,381.72	$ 32,221.68	11
0.11	$ 42,389.58	$ 35,934.10	$ 32,866.11	12
0.11	$ 43,449.32	$ 36,498.00	$ 33,523.44	13
0.12	$ 44,535.56	$ 37,073.65	$ 34,193.90	14
0.12	$ 45,648.95	$ 37,661.30	$ 34,877.78	15
0.12	$ 46,790.17	$ 38,261.19	$ 35,575.34	16
0.12	$ 47,959.92	$ 38,873.58	$ 36,286.84	17
0.13	$ 49,158.92	$ 39,498.72	$ 37,012.58	18
0.13	$ 50,387.89	$ 40,136.88	$ 37,752.83	19
0.13	$ 51,647.59	$ 40,788.32	$ 38,507.89	20
0.13	$ 52,938.78	$ 41,453.32	$ 39,278.05	21
0.14	$ 54,262.25	$ 42,132.16	$ 40,063.61	22
0.14	$ 55,618.81	$ 42,825.12	$ 40,864.88	23
0.14	$ 57,009.28	$ 43,532.48	$ 41,682.18	24
0.14	$ 58,434.51	$ 44,254.56	$ 42,515.82	25
Base Model Average Yearly Cost	**$ 33,866.28**	**$ 33,866.28**	**$ 33,866.28**	
Average Annual Cost of Power with Solar Array	$ 44,141.40	$ 36,804.58	$ 33,866.28	
Average Yearly Difference In Energy Cost	$ (10,275.12)	$ (2,938.31)	$ -	

Section 3: Objective 2 Small-Scale Solar

3.1: Methods

This project would consist of the transition from current high-pressure, sodium, street-lights, to solar powered LED street lights. In order to retain the unique, late nineteenth to early twentieth century New England style aesthetic exhibited by the Historic District, one of the first actions performed was to collect information in regards to the style and light type. The specific style of the light fixture was determined through meeting with city official, Lee Brown, within the office of planning and development. It was found that the fixtures, most notably defined by the bulbous glass housing which encapsulates the bulb, are acorn all-glass globes. Next, in order to ensure consistency, the type of light emitted was surveyed through field observation. The Kelvin Color Correlation scale was used as a standard reference (see Figure 2). The scale operates such that higher values indicate a “cooler” white to blue light, while lower values indicate a “warm” light being emitted with a yellow to orange appearance. Through the aforementioned field surveying conducted at night, it was determined that Worthington’s fixtures fell between 1800 and 2200K. This is typical of a standard high-pressure sodium bulb, and reminiscent of yellow-orange candlelight that helps to create the aesthetic upheld in the Historic District.

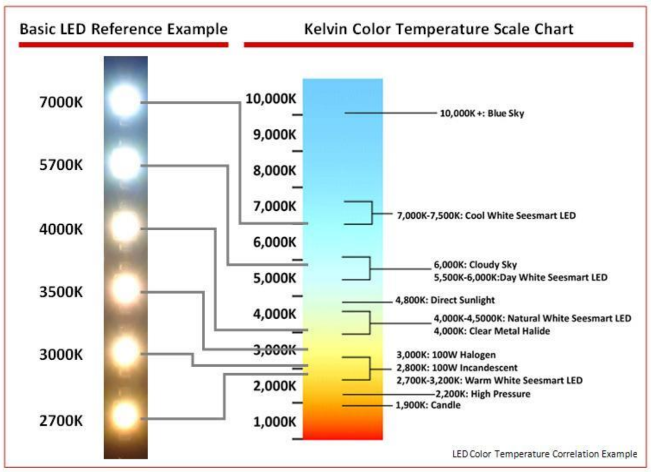

Figure 2: *Kelvin Color Scale for LED Lights*

After determining the required physical appearance needed, we evaluated how to make the transition to solar. Keeping in line with principles of fiscal responsibility vital to the municipality, we determined that the most cost effective and least-intensive means of affecting change in a positive and sustainable way would be to convert the current fixtures to solar powered LED lights.

In order to gauge cost projections, baseline data was gathered with respect to run cost of fixtures (both traditional and LED) the projected installation costs, as well as the costs of acquiring the new fixtures themselves. Utility data was gathered to forecast potential cost savings, and the average maintenance cost was estimated based on similar municipalities. Once all essential data was collected, a cost benefit analysis was run for the purpose of determining feasibility. It was decided that for the purposes of comparison, the trial group of retrofitted lights would consist of 100 units, which would be significant enough to show measurable progress should the idea be fiscally feasible.

3.2: Results:

The best course of action is to retrofit the current high pressure sodium lights because it creates the highest cost savings. This decision was reached after reviewing the US Department of Energy's Municipal Solid State Lighting Consortium, a government initiative to encourage and provide information for municipalities who may be considering making the switch to solar/ high efficiency LED street lights. (DOE-MSSLC, 2016).

Once the scope for the project was established, it was critical to find a fixture which could act as a direct replacement for the fixtures currently in use without compromising the aesthetic. It was determined that the best candidate was a SEPCO LDN- London Solar Light Fixture (SEPCO, 2016). This fixture is made of cast aluminum with a decorative acorn-style glass housing and comes with the driver required to operate the fixture alongside solar charged batteries. This complete solar lighting systems also includes the solar power assembly with mounting, battery assembly, fixture and fixture mounting bracket. The cost for the kit is valued at $400. That rate, across the total initial fixture count of 100 would bring the fixture expenditure cost to $40,000. The installation costs were estimated based upon similar municipality expenditures found from Leotek estimates. At a rate of 1 unit per hour for a 2-person team, with each member having a salary of $25/hr (Leotek, 2016), the projected installation expenditure would constitute an additional $5000, bringing the total upfront expenditure to $45,000.

Once this critical information was gathered, a cost benefit analysis was run to determine if the efficiency increases generated from the transition from HPS bulbs to a Solar LED bulb would be worth the investment. The calculations found in Figure 3 (Appendix) represent the return on capital expenditure across a 10-year period. The operational costs of the high pressure sodium for an individual light in a 400w system was found to be $144/year. This was based on an average run time of 7 hours per night, at the standard rate of .09 cents/ Kwh. This would total $14,400 across the cumulative 100 lights within the scope of the project. By comparison, the solar LED lights operate at a level of 65% increased efficiency to that of the HPS system, as it only requires 175w for the same luminary output. This coupled with the increased life expectancy of both the bulb, and the system components themselves by a magnitude of 10, i.e. the system is built to function for 100,000 hours compared to the priors 10,000 hours made for a compelling result (Tuscon, 2010).

We found that the expected run cost for a solar LED fixture would be $50.40 per year. This constitutes a savings of $93.60 per light, compared to the traditional HPS fixture. Across the sample group, we find a total annual cost savings of $9360 per year. Figure 3 (Appendix) shows the Cost Recovery Schedule for the initial capital expenditure. The net discounted cash flow reflects a 2% per year, projected increase in electricity costs. The undiscounted payback period is an estimated 4.88 years, but when reflected to include the monetary time value of the initial expenditure, we see the true payback period becomes 5.048 years. As shown, the return for the cash flow, based on reduced infrastructure expenditure is an annual rate of 20.59%. [1]

[1]During our poster presentation we were informed about an AEP program that will subsidize the cost of solar LED lights. These savings were not used in our calculations, but should be explored if Worthington decides to go ahead with this project.

Section 4: Objective 3- Energy Efficiency Investments

4.1: Methods

Because of the likely high costs of solar in Worthington, we also researched low-cost ways to reduce energy consumption in buildings. First, we gathered information on the buildings in the Historic District. We wanted to select a medium sized building, in a prime location that we could use as an example for implementing low-cost energy efficiency upgrades. We also researched if any of the buildings had renovation plans. It would be more cost-effective and sustainable to implement energy saving updates in buildings that already had planned renovations. Additionally, we thoroughly read through academic literature and other online resources regarding the best ways to retrofit historic buildings to improve energy efficiency. Three energy-use areas (lighting, air filtration, and water) were identified and low-cost solutions were compared in simple cost-benefit analyses.

4.2: Results

According to *Energy and Buildings*, there are five phases for retrofitting existing buildings. Phase one is a pre-retrofit survey and project set up to determine the scope and targets. Phase two is a building energy audit and a performance assessment. Phase three identifies the retrofit options by performing risk assessments, economic analyses, and energy saving estimations. Phase four tests and implements on the site and, phase five validates and verifies the savings (Cooper & Al., 2012).

To reduce energy costs and carbon emissions, we suggest Worthington invests in energy audits of its buildings that make up the Historic District. Reported costs for detailed energy audits vary from between $0.12 and $0.50 per square foot depending on size and complexity of the building. However, in many cases, the audit costs are paid back within the first year through energy savings (Baechler et Al., 2011). Because of the scope of this project and our limited level of expertise in the area, our group was unable to perform a true energy audit for each of the buildings in Worthington. Instead, we identified a model building where small-low cost solutions could be implemented.

Kilbourne Memorial Library was selected as the model building. The building was originally constructed in 1927 and was used as a city library and for school board offices. In 2006, the City acquired it. Currently, half of the building is rented to a private business called *Sew to Speak* and the other half of the building is vacant, but there are plans to make it a co-working and maker space. It is an 11,000 square foot building located in the Village Green at the northeast corner of the intersection of State Route 161 and High Street. The southern half of the building, covering about 2,000 square feet, was renovated in 2015/2016. The rest of the building is supposed to be renovated this year and into 2017 (Stewart, personal communication, 10/14/16). Currently, there are no specific renovation plans for the building. For this reason, our focus was to compare between potential alternatives, instead of baseline renovation plans.

When considering upgrades to Kilbourne Memorial Library, we focused on solutions with the greatest cost savings, without compromising the historic character of the building. Throughout the research process, many ideas were considered such as window replacement, adding insulation, switching to a tank-less, hot water heater among other ideas. However, these solutions either threatened the historic character of the building or were too expensive for the focus of our objective. Three general areas we found to be most promising for upgrades were (1) heating and cooling, (2) lighting, and (3) water. We were unable to access specific energy data on Kilbourne Library, but our calculations and prices are from buildings that are of similar size and within the Worthington zip code.

If windows are not in proper condition, they can cause higher-energy bills because of a loss of heat or cool air through gaps or cracks. Total window replacement is not suggested for retrofitting historic building because windows are a key feature to the character of a building. Also, the cost of total window replacement is very high in comparison to other alternative methods, which produce similar savings. For that reason, our group did not investigate total window replacement any further. Table 3 shows the two alternative methods we investigated: weather stripping and storm windows.

Weather stripping seals air leaks and insulates a building's interior by adding material such as metal or plastic around doors and windows. Storm windows are windows that are put on the inside or outside of the main glass windows of a house or building. As you can see in Table 2, the average cost for weather stripping 10 windows was about $1,098.70 and the average cost was $4,200.00 for adding storm windows to an existing 10 windows. The estimated heating bill for the 11,000 square foot Kilbourne Memorial Library is $26,433 (based off a $.09/KwH, and estimated 26.7kWh per square foot). Weather stripping can create savings of 10-15% annually (Vaglica, 2016). Alternatively, adding low emissivity (low-e) storm windows can reduce heating and cooling expenses by between 12 to 33% ("Savings Project", 2016). These percentages were used to estimate the low and high savings. The cost per window for storm windows was estimated to be from $90-$140 plus the installation fee of between $30 and $65 per hour for two hours ("How Much Do Storm Windows Cost", 2016). For weather stripping, the cost was based off of local window estimates using the Worthington zip code ("Cost to Install Window Weather Stripping", 2016). The results of Table 2 showed that after one year, the annual savings, discounted one year, compared to the upfront cost for weather-stripping was $2,197.04 and for storm windows was $1,630,81.

Table 3: Window Comparisons

Windows									
	High Price Per Window	Low Price for Window	Number of Windows	Average Cost for 10 windows	High Estimate of Savings	Low Estimate for Savings	Average Annual Savings	NPV of Savings	Present Value Benefits-Costs
Weatherstripping	$ 77.02	$ 27.21	10	$ 1,042.30	$ 3,964.95	$ 2,643.30	$ 3,304.13	$3,239.34	$2,197.04
Storm Windows	$ 270.00	$ 150.00	10	$ 4,200.00	$ 8,722.89	$ 3,171.96	$ 5,947.43	$5,830.81	$1,630.81

For lighting, we compared three different types of light bulbs: LED, incandescent, and compact fluorescent. The data was standardized based on the amount of lumens (light) for an equivalent 60 KWh incandescent light bulb ("LED Light Bulbs", 2014). The costs per bulb were used from home-depot prices and the data was compared for 50,000 hours of use. The results of this comparison can be seen in Table 4.

Table 4: Light Comparisons

Lights								
	Bulb Lifespan (hours)	Watts per bulb (eq. 60 watts)	Cost per bulb	KWh of electricity used over 50k hours	Cost of electricity ($.09 per KWh)	Bulbs need for 50k use	Bulb Expense	Total Cost for 50k hours
LED	50000	10	$ 4.50	500	$ 45.00	1	$ 4.50	$ 49.50
Compact Fluorescent	10000	14	$ 2.20	700	$ 630.00	5	$ 11.00	$ 641.00
Incandescent	1200	60	$ 1.25	3000	$ 2,700.00	42	$ 52.50	$ 2,752.50

The last component we looked into was different GPM (gallon per minute) faucet aerators. Table 5 is based on the assumption that Kilbourne Memorial Library has a normal flow rate of 2.2 GPM and that the sink is in use for about 30 minutes a day. This is about 66 gallons per day and at a price of $2 per 1000 gallons for water, the annual water cost is about $48.00 (Moloney, 2014).

Table 5: Faucet Aerator GPM Comparisons

Faucet Aerator			
GPM	Percent Savings	Annual Savings	Payback Period (months)
1.5	32%	$ 15.36	3.9
1	55%	$ 26.40	2.3
0.5	78%	$ 37.44	1.6
0.35	85%	$ 40.80	1.5

Recommendations:

Currently, we do not think that a large scale solar project is financially feasible in the Historic District of Worthington. However, our group recommends that the City of Worthington would benefit substantially from moving forward with a plan to retrofit current HPS streetlights with solar powered LED fixtures. With a net payback period of roughly 5 years, tangible savings can be realized with each consecutive year. We believe that this would not only reduce the burden of municipality expenditures, but also hold consistent with patterns of excellence in governance exhibited by the city. There are already plans to replace current streetlights to LED, but there is currently no budget set aside for this project. We think Worthington should create a budget that allows for the conversion to LED solar street lights rather than just LED street lights. Additionally, we suggest weather stripping windows, switching to LED lights, and also adding faucet aerators to the renovation plans of Kilbourne Memorial Library. Since all of the GPM faucet aerators have a payback period within the first 4 months, Worthington should select the water pressure of their preference. The renovations in this building should be a model that can be repeated for other renovations in the district. Moving forward, Worthington should audit all their buildings to find building-specific energy savings.

Conclusion:

Through research, interviews, and cost benefit analyses, we have concluded that Worthington's Historic District is a promising area for sustainability in the energy sector. Although large scale solar is not financially feasible at the moment, small scale solar is as well as energy saving techniques that can be implemented into buildings already being renovated. These can both save money in the long run and allow Worthington to set the precedent for other Ohio suburbs. Unlike natural gas and coal, solar power is a source of energy that will never run out, and it emits zero carbon dioxide or other pollutants, which means cleaner air and a cooler climate for generations to come. Achieving sustainable development in Old Worthington does not have to be an all or nothing process, but a journey that is undertaken one small change at a time, using the proposed methods found to be economic and feasible through our research.

Appendix

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Table 1: Masonic Lodge Large Scale Solar 25 Year Projected Cost

Masonic Lodge 48 kWh System Running Cost

Year	Average Annual Consumption - Solar Production (kWh)	Production (kWh)	Direct Purchase Cost ($)	O&M Cost ($)	PPA Escalator (%)	PPA Rate ($/kWh)	Estimated AEP Power Price (2.2% Annual Increase $/kWh)	Average Annual Energy Cost (PPA)	Average Annual Energy Cost (Purchased from Local Utility)	Average Annual Energy Cost (Solar Loan 4.5%)+(Power Purchased from Local Utility)
0			$ 136,800.00		-					
1	234,493	59,207		$ 1,440		$ 0.12	0.10	$ 35,244.00	$ 29,370.00	$ 32,787.34
2	234,789	58,911		$ 1,469	2.40%	$ 0.12	0.10	$ 36,089.86	$ 29,957.40	$ 33,286.52
3	235,084	58,616		$ 1,498	2.40%	$ 0.13	0.10	$ 36,956.01	$ 30,556.55	$ 33,796.14
4	235,377	58,323		$ 1,528	2.40%	$ 0.13	0.11	$ 37,842.96	$ 31,167.68	$ 34,316.40
5	235,668	58,032		$ 1,559	2.40%	$ 0.13	0.11	$ 38,751.19	$ 31,791.03	$ 34,847.53
6	235,958	57,742		$ 1,590	2.40%	$ 0.14	0.11	$ 39,681.22	$ 32,426.85	$ 35,389.76
7	236,247	57,453		$ 1,622	2.40%	$ 0.14	0.11	$ 40,633.57	$ 33,075.39	$ 35,943.31
8	236,534	57,166		$ 1,654	2.40%	$ 0.14	0.11	$ 41,608.77	$ 33,736.90	$ 36,508.41
9	236,820	56,880		$ 1,687	2.40%	$ 0.15	0.12	$ 42,607.38	$ 34,411.64	$ 37,085.31
10	237,105	56,595		$ 1,721	2.40%	$ 0.15	0.12	$ 43,629.96	$ 35,099.87	$ 37,674.24
11	237,388	56,312		$ 1,755	2.40%	$ 0.15	0.12	$ 44,677.08	$ 35,801.87	$ 38,275.46
12	237,669	56,031		$ 1,790	2.40%	$ 0.16	0.12	$ 45,749.33	$ 36,517.90	$ 38,889.22
13	237,949	55,751		$ 1,826	2.40%	$ 0.16	0.13	$ 46,847.31	$ 37,248.26	$ 39,515.77
14	238,228	55,472		$ 1,863	2.40%	$ 0.16	0.13	$ 47,971.65	$ 37,993.23	$ 40,155.38
15	238,505	55,195		$ 1,900	2.40%	$ 0.17	0.13	$ 49,122.97	$ 38,753.09	$ 40,808.33
16	238,781	54,919		$ 1,938	2.40%	$ 0.17	0.13	$ 50,301.92	$ 39,528.15	$ 41,474.88
17	239,056	54,644		$ 1,977	2.40%	$ 0.18	0.14	$ 51,509.16	$ 40,318.72	$ 42,155.31
18	239,329	54,371		$ 2,016	2.40%	$ 0.18	0.14	$ 52,745.38	$ 41,125.09	$ 42,849.91
19	239,601	54,099		$ 2,057	2.40%	$ 0.18	0.14	$ 54,011.27	$ 41,947.59	$ 43,558.98
20	239,872	53,828		$ 2,098	2.40%	$ 0.19	0.15	$ 55,307.54	$ 42,786.54	$ 44,282.80
21	240,141	53,559		$ 2,140	2.40%	$ 0.19	0.15	$ 56,634.92	$ 43,642.28	$ 45,021.69
22	240,409	53,291		$ 2,183	2.40%	$ 0.20	0.15	$ 57,994.16	$ 44,515.12	$ 45,775.95
23	240,675	53,025		$ 2,226	2.40%	$ 0.20	0.15	$ 59,386.02	$ 45,405.42	$ 46,545.90
24	240,940	52,760		$ 2,271	2.40%	$ 0.21	0.16	$ 60,811.29	$ 46,313.53	$ 47,331.87
25	241,204	52,496		$ 2,316	2.40%	$ 0.21	0.16	$ 62,270.76	$ 47,239.80	$ 48,134.17
Total kWh Produced Over 25 Years		1,394,677.22	$ 136,800	$ 46,124			Totals	$ 1,188,385.67	$ 940,729.90	$ 996,410.57
System Cost+O&M			$ 182,924							

year	Cash Flow	Net Cash Flow	Discounted Cash Flow	Net Discounted Cash Flow
0	-45000	-45000	-45000	-45000
1	9360	-35640	8914.29	-36085.71
2	9828	-25812	8914.29	-27171.43
3	10319.4	-15492.6	8914.29	-18257.14
4	10835.37	-4657.23	8914.29	-9342.86
5	11377.14	6719.91	8914.29	-428.57
6	11946	18665.9	8914.29	8485.71
7	12543.3	31209.2	8914.29	17400
8	13170.46	44379.66	8914.29	26314.29
9	13828.98	58208.64	8914.29	35228.57
10	14520.43	72729.07	8914.29	44142.86

Payback Period

With Steady Cash Flow

Result

Payback Period: 4.388 years

Discounted Payback Period: 5.048 years

Return for the Cash Flow: 20.59% per year

Figure 3: Capital Expenditure Cost Recovery for Solar LED Lighting