Expert Match

C2C: Clean Energy to Communities
U.S. DEPARTMENT OF ENERGY

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Photovoltaic and Cost Analysis for Winston-Salem, North Carolina

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Overview

The feasibility of solar installations depends on several factors, including the solar resource available at each site, electricity costs, and the area available for photovoltaic (PV) systems. While different periods of electricity consumption may influence how solar energy offsets usage, the primary considerations for feasibility are the solar resource, cost of electricity, and space for installation, particularly in the absence of detailed hourly load data (Schiavone, D., 2024). The steps explained below were applied to each of the locations to calculate the preliminary photovoltaic (PV) system size. To determine the appropriate size for a PV system, the first step is calculating the daily energy requirement (kWh/day), which is typically based on the annual electricity use of the installation. However, relying solely on annual consumption figures can be misleading, as energy demand is not constant throughout the year. Variations in usage due to seasonal changes, operational hours, and occupancy levels can significantly impact daily energy needs, potentially leading to an undersized or oversized PV system if not accounted for properly. Next, we utilize regional solar data, such as the National Solar Radiation Database (NSRDB), to determine the average peak sun hours. Peak sun hours refer to the hours during which solar irradiance reaches a level sufficient for effective energy generation, typically defined as 1,000 watts per square meter (Schiavone, D., 2024). Essentially, one peak sun hour is equivalent to receiving 1 kWh of energy per square meter in a day. In Winston-Salem, the average peak sun hours are approximately 4.5 hours per day, meaning that, on average, each square meter of solar panel receives enough sunlight to generate about 4.5 kWh of energy daily. This analysis aims to ensure reliable energy performance while considering cost savings through effective sizing of the PV system.

This calculation results in systems sized for each month, considering the variations in solar irradiance throughout the year. We then derive the average of these monthly sizes and apply a safety margin coefficient of 1.2 to ensure reliable performance and accommodate unexpected variations. In such cases, relying solely on monthly averages may not be sufficient, as peak loads can significantly exceed daily averages. To address these challenges, a more detailed approach involves conducting a parametric analysis using tools like the System Advisor Model (SAM), which allows us to evaluate how solar resource variations manifest over a year or more. By sizing the PV array based on the solar resource scenarios. We take a cautious approach to improve our ability to handle changes in energy demand and supply. Throughout the study, the “maximum PV size for the roof” is determined based on the available space on each building for implementing the new system. In each case, the PV system is sized to match available roof space.

Another critical factor is the revenue payback period. Based on our findings, a coverage threshold of 70% or higher seems to offer significant advantages for our solar installations. The term "coverage threshold" refers to the proportion of energy demand that can be met by the solar system relative to the total energy consumption of a facility. In this context, achieving a coverage threshold of 70% means that the solar installation can supply 70% of the facility’s energy needs, which enhances the economic viability and sustainability of the project. The choice of the 70% value was based on several factors. This level of coverage is often considered a balanced target that maximizes both energy savings and the return on investment while also providing a buffer against fluctuations in energy production due to variable solar resources. Systems that meet or exceed this threshold can effectively reduce electricity costs, improve energy resilience, and contribute positively to overall energy management goals. For small sites that are considered excellent for solar PV, such as Fire Station #3 and Reynolds Park, investment costs should be covered within 15-25 years. For larger sites, investment recovery should be viable within 25 to 30 years, such as at the Police Firing Range & Training Center, making it a good option despite the potential for economies of scale. The Police

Firing Range and Training Center's 41% coverage falls short, but it has a feasible payback period due to a different rate cost in Winston-Salem's tariff. In order to review the feasibility for other sites, the 70% threshold can be applied as a guideline, as well as the expected average of 25 years payback period previously mentioned . These techniques help with locating the best PV system application based on revenue.

Methods

To effectively size the PV system, calculations start by determining the daily energy requirement, which is denoted as A kWh/day. This value represents the total energy needs of the installation. The daily energy requirement is calculated based on the installation's annual electricity usage. Next, we utilize regional solar data, such as the National Solar Radiation Database (NSRDB), to identify the average peak sun hours available at the site. In Winston-Salem, for example, the average peak sun hours are approximately B kWh/m²/day, equivalent to about 4.5 kWh/m²/day. Peak sun hours indicate the hours during which solar irradiance reaches a level sufficient for effective energy generation, typically defined as 1,000 watts per square meter. To estimate the energy generated by the PV arrays, we calculate the daily energy generation per kW of PV capacity, denoted as C kWh/kW of capacity per day. This calculation accounts for the system efficiency factor, which in this case is set at 85% to reflect losses due to various components, such as inverter efficiency, shading, and temperature effects. The effective generation can be calculated as follows:

$$C = B \times Efficiency\ Factor \tag{1}$$

With the daily energy requirement and the effective generation per kW established, we can determine the required PV capacity using the following equation:

$$Required\ PV\ Capacity\ (kW) = \frac{A}{C} \tag{2}$$

This equation provides the necessary capacity of the PV system to meet the energy needs of the installation. (Go Green Solar)

Finally, to determine the space required for the PV installation, denoted as F m² (Raman, M., 2024), we multiply the required capacity by the area needed per kW of PV capacity:

$$F = Required\ PV\ Capacity\ (kW) \times Area\ per\ kW\ (\frac{m^2}{kW}) \tag{3}$$

By following this systematic approach, we can accurately size the PV system to meet the daily energy requirements while taking into account local solar resources and system efficiencies. This method ensures that the installation is neither undersized nor oversized. Tools like Google Earth were utilized to estimate the roof area for each installation site. This information was combined with the required PV capacity to calculate an adjusted PV size using the System Advisor Model. The

adjusted size takes into account the dimensions of the selected PV panels, ensuring that the system is tailor to the available roof area to ensure optimal performance.

The feasibility factor calculated in each case was derived from the approach outlined by (Reca et al., 2015). It evaluates the effectiveness of a solar energy system in reducing electricity consumption. The provided equation can be interpreted as a Feasibility Factor (FF):

$$FF = 1 - (\frac{E_G - E_{AC}}{E_G}) \times 100 \quad (4)$$

Where E_G is electricity use without system and E_{AC} refers to energy generated and supplied by the solar energy system. This represents the total amount of electricity consumed by a facility or installation before the integration of the solar energy system. The numerator represents the remaining electricity needed after the solar system's contribution. It represents the actual energy produced and used from the solar panels. This equation serves as a useful metric for calculating the effectiveness of a solar energy system in meeting a facility's electricity demands. A higher feasibility factor signifies greater reliance on solar energy and less dependence on external electricity sources. A Feasibility Factor of 100% Indicates that the solar energy system meets all the electricity needs, meaning no additional electricity is needed from the grid.

The total installed cost per capacity of $2.5/Wdc was provided by the Winston-Salem committee for this project. To calculate the LCOE from (U.S. Department of Energy, 2015), the overall system cost is determined by multiplying the system capacity (in kW) by the installed cost rate of $2.5 per Wdc. This total system cost serves as the basis for the LCOE calculation. The formula for the LCOE for the first year is :

$$LCOE_{Year\ 1} = \frac{Cost_{Total} - Bill_{System}}{Total\ Energy} \quad (5)$$

Where $Cost_{Total}$ is the total cost of the PV system installation, $Bill_{System}$ is the reduced electricity bill after the system is installed and Total Energy is the amount of energy the system generates in the first year. For year n, the LCOE can be calculated by adding the LCOE from year 1 to the difference between the electricity bills with and without the system, divided by the energy produced in Year n:

$$LCOE_{Year\ n} = LCOE_{Year\ 1} + \frac{\sum_{t=1}^{n} Bill_{Non-System_t} - Bill_{System_t}}{\sum_{t=1}^{n} Total\ Energy_t} \quad (6)$$

This formula calculates the total cost savings over n years and divides it by the total energy produced over the same period. Where $Bill_{Non-System_t}$ is the electricity bill for each year without the solar system, $Bill_{System_t}$ is the reduced electricity bill with the solar system and $Bill_{System_t}$ is the energy generated by the system each year. The formula sums the savings (the difference between bills with and without the system) over n years and divides by the total energy produced during those years, giving a cumulative LCOE over the n-year period.

Fire Station #3

The analysis for Fire Station #3 indicates that it is an excellent option for solar PV installation. With a calculated system size of 32.3 kW, the available area of approximately 115 m² reduces the maximum system size to 22.3 kW, representing a 31% reduction. The feasibility study indicates that a solar installation will cover at least 88.8% of the building's electricity consumption.

Photovoltaic Sizing / System Advisor Model Analysis

The following information details the component specifications and PV sizing, obtained using the SAM. The PV modules selected for this system are the SunPower SPR-E19-310, which is a 310-watt panel, paired with the SunPower SPR-12000-3 [480] inverter, offering a maximum power output of 12.2 kW. For further information on component characteristics, please refer to the Appendix.

The following sizing specifications and details were obtained using the SAM:

- Modules per string: 9,8,7
- Strings in parallel: 3
- Subarray: 3
- Number of modules: 72
- Inverter maximum input voltage: 800V
- Voc at reference conditions (V): 579.6, 515.2, 450.8
- Number of inverters: 2

For more information on component characteristics, please refer to the Appendix.

Generation Analysis:

The generation analysis provides information on the cost savings and energy production achieved with the installed PV system, including demand coverage, efficiency, and cost-effectiveness.

- Total electricity bill with system: $680.16
- Total electricity bill without system: $4,801.67
- Total electricity consumption (kWh/yr): 37,657
- Total electricity use without system (kWh/yr): 4,218 (11.2%)
- Total AC energy (kWh/yr): 33,438
- Total installed cost: $55,750.00
- Total installed cost per capacity: $2.5/Wdc

Tables

Table 1: Generation Analysis Data

	AC energy (year 1) (kWh/mo)	DC energy (kWh/mo)	Electricity use without system (kWh/mo)	Electricity bill with system ($/mo)	Electricity bill without system ($/mo)
Jan	2387.76	2496.07	3025	72.7052	387.696
Feb	2226.05	2332.42	2488	51.0881	318.723
Mar	2905.61	3042.27	2157	36	276.035
Apr	3248.37	3399.49	2899	36	369.054
May	3324.94	3481.29	2885	36	365.198
Jun	3340.37	3499.19	3062	36	387.274
Jul	3289.07	3445.2	4441	36	556.243
Aug	3087.06	3233.38	4420	74.51	551.974
Sep	2886.21	3022.73	4287	116.686	538.851
Oct	2522.48	2642.92	3194	74.6794	402.132
Nov	2325.54	2434.32	2459	43.6871	312.098
Dec	1895.33	1987.92	2340	61.613	299.72

Table 2: Levelized Cost of Energy (LCOE)

Years	LCOE
1	1.67
5	0.3334
10	0.1667
15	0.1111

Table 3: Revenue for First 15 Years

Figures

Figure 1: Fire Station #3 – Image from Google Maps

Figure 1 illustrates a possible layout for the solar system at Fire Station #3.

Police Firing Range and Training Center

The analysis for the Police Firing Range & Training Center indicates that it is a good option for solar PV installation. With a calculated system size of 525 kW, the available area of approximately 1,614 m² reduces the maximum system size to 307 kW, representing a 41% reduction. The feasibility study indicates that a solar installation will cover at least 41.8% of the building's electricity consumption.

Photovoltaic Sizing / SAM Analysis

The following information details the component specifications and PV sizing, obtained using the SAM. The PV modules selected for this system are the SunPower SPR-E19-310, which is a 310-watt panel, paired with the SunPower SPR-15000-3 [480] inverter, offering a maximum power output of 15.3 kW. For further information on component characteristics, please refer to the Appendix.

The following sizing specifications and details were obtained using the SAM:

- Modules per string: 30
- Strings in parallel: 9,8,8,8
- Subarray: 4
- Number of modules: 990
- Inverter maximum input voltage: 800V
- Voc at reference conditions (V): 1,932
- Number of inverters: 18
- Total module area (m^2): 1,614

For more information on component characteristics, please refer to the Appendix.

Generation Analysis

The generation analysis provides information on the cost savings and energy production achieved with the installed PV system, including demand coverage, efficiency, and cost-effectiveness.

- Total electricity bill with system: $46,021.79
- Total electricity bill without system: $62,280.54
- Total electricity consumption (kWh/yr): 612,323
- Total electricity use without system (kWh/yr): 356,224 (58.2%)
- Total AC energy (kWh/yr): 256,098
- Total installed cost: $767,500.00
- Total installed cost per capacity: $2.5/Wdc

Tables

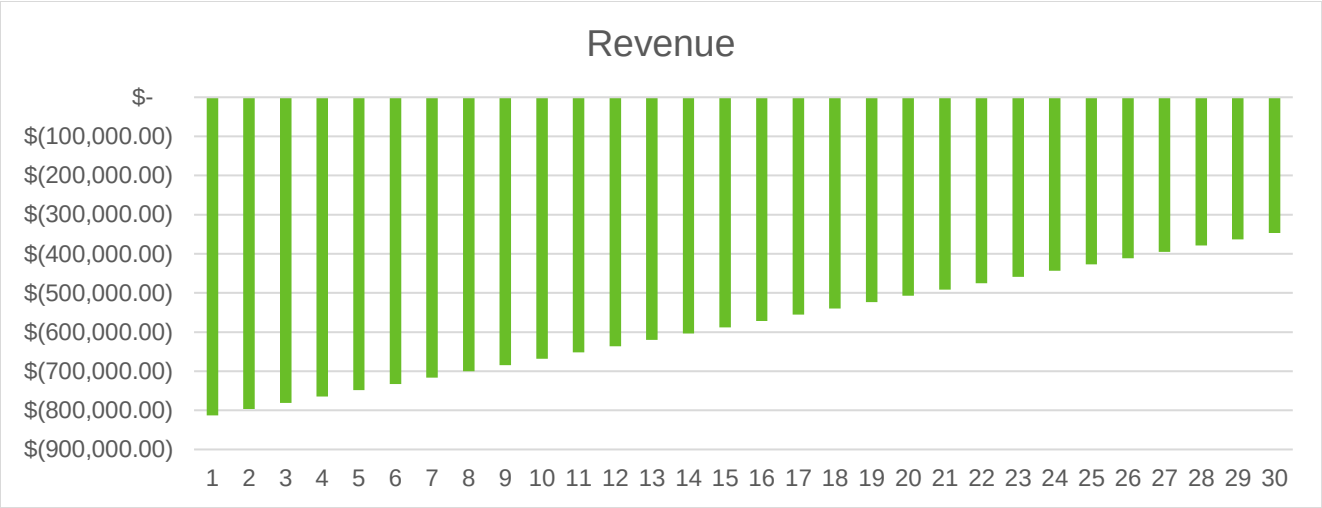
Table 4: Generation Analysis Data

	AC energy (year 1) (kWh/mo)	DC energy (kWh/mo)	Electricity use with system (kWh/mo)	Electricity bill with system ($/mo)	Electricity bill without system ($/mo)
Jan	16890.2	17510.6	25377.8	3482.93	4632.39
Feb	16112.7	16734.4	21899.3	2894.12	4217.09
Mar	21295.8	22083.7	24345.2	3165.14	4430.79
Apr	24640.6	25519	21353.4	3074.15	4620.72
May	26032.2	26965.6	23780.8	3318.76	4856.88
Jun	26754.6	27713.4	22391.4	3054.26	4716.37
Jul	26541.3	27493.2	36188.7	4439.11	6115.14
Aug	24921.2	25812.4	42556.8	4957.5	6486.42
Sep	22870.4	23689.4	46584.6	5644.99	7001.17
Oct	19243.1	19959.3	37647.9	4646.59	5767.87
Nov	17200	17838.6	26854	3387.88	4427.64
Dec	13596.7	14146.6	27244.3	3441.47	4311.26

Table 5: Levelized Cost of Energy (LCOE)

Years	LCOE
1	3.00
5	0.60
10	0.30
15	0.20
20	0.15
30	0.10

Table 6: Revenue for First 30 Years



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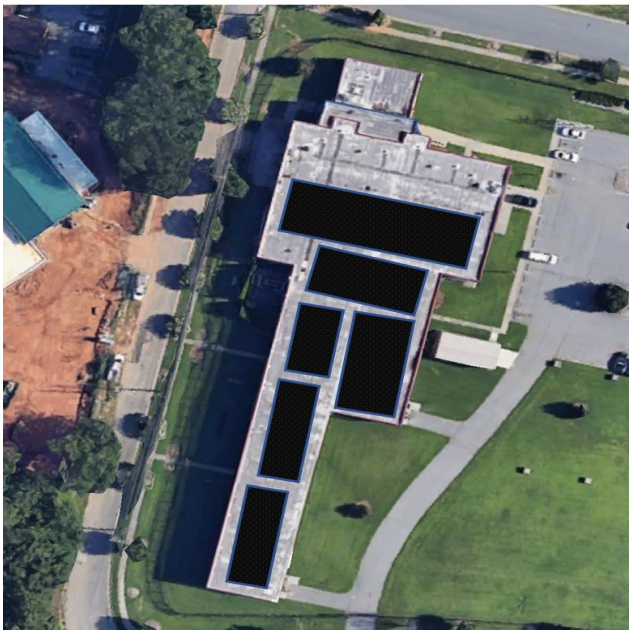

Figure 2: Police Firing Range and Training Center – Image from Google Maps

Figure 2 illustrates a possible layout for the solar system at the Police Firing Range and Training Center.

Bus Station (100 W 5th St.)

The bus station analysis indicates that it is not a viable option, with a calculated size of 229 kW, an approximate area of 1,300 m², which reduces the maximum PV size to a 198 kW system. This attains for a 14% reduction. The feasibility of a solar installation shows that it can cover at least 67.1% of the building's electricity consumption.

Photovoltaic Sizing / SAM Analysis

The following information details the component specifications and PV sizing, obtained using the SAM. The PV modules selected for this system are the SunPower SPR-E19-310, which is a 310-watt panel, paired with the SunPower SPR-15000-3 [480] inverter, offering a maximum power output of 15.3 kW. For further information on component characteristics, please refer to the Appendix.

The following sizing specifications and details were obtained using the SAM:

- Modules per string: 20
- Strings in parallel: 8
- Subarray: 4
- Number of modules: 640
- Inverter maximum input voltage: 800V
- Voc at reference conditions (V): 1,288
- Number of inverters: 12
- Total module area (m^2): 1,043

For more information on component characteristics, please refer to the Appendix.

Generation Analysis

The generation analysis provides information on the cost savings and energy production achieved with the installed PV system, including demand coverage, efficiency, and cost-effectiveness.

- Total electricity bill with system: $20,893.31
- Total electricity bill without system: $33,566.55
- Total electricity consumption (kWh/yr): 369,383
- Total electricity use without system (kWh/yr): 121,566 (32.9%)
- Total AC energy (kWh/yr): 247,816
- Total installed Cost: $496,250.00
- Total installed cost per capacity: $2.5/Wdc

Tables

Table 7: Generation Analysis Data

	AC energy (year 1) (kWh/mo)	DC energy (kWh/mo)	Electricity use without system (kWh/mo)	Electricity bill with system ($/mo)	Electricity bill without system ($/mo)
Jan	16366.7	16901.9	29740	1445.31	2092.96
Feb	15618.3	16150.4	28237	1507.44	2125.46
Mar	20627.1	21312.3	28154	1215.04	1951.05
Apr	23843.7	24614.6	30818	1478.1	2539.45
May	25179.5	25993.8	27394	878.408	2254.87
Jun	25854.6	26692.1	28617	1159.36	2695.64
Jul	25646.4	26474.7	30450	1203.67	2759.14
Aug	24080	24854.4	38070	2317.57	3396.6
Sep	22112.3	22827.7	38386	2830.46	3752.19
Oct	18632.7	19251.7	32765	1911.86	2649.25
Nov	16663.9	17213.9	29033	1478.7	2138.12
Dec	13190.9	13654.2	27719	1451.89	1973.78

Table 8: Levelized Cost of Energy (LCOE)

Years	LCOE
1	2.00
5	0.4004
10	0.2002
15	0.1334
20	0.1001
30	0.0667

Table 9: Revenue for First 30 Years

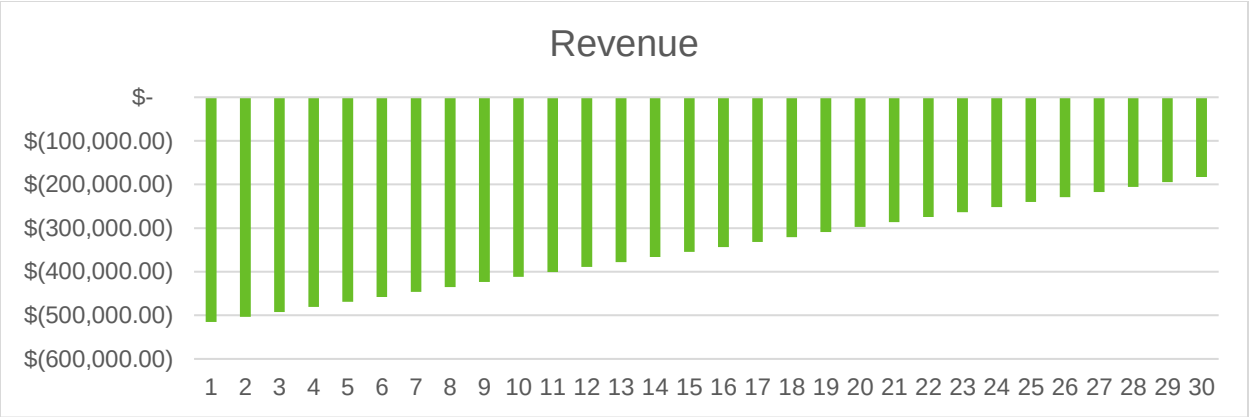

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Figure 3: Bus Station (100 W 5th St.) – Image from Google Maps

Figure 3 illustrates a possible layout for the solar system at the bus station.

Reynolds Park (Anderson)

The analysis for Reynolds Park indicates that it is an excellent option for solar PV installation. With a calculated system size of 65 kW, the available area of approximately 332 m² reduces the maximum system size to 63 kW, representing a 3% reduction. The feasibility study indicates that a solar installation will cover at least 90.8% of the building's electricity consumption.

Photovoltaic Sizing / SAM Analysis

The following information details the component specifications and PV sizing, obtained using the SAM. The PV modules selected for this system are the SunPower SPR-E19-310, which is a 310-watt panel, paired with the SunPower SPR-12000-3 [480] inverter, offering a maximum power output of 12.2 kW. For further information on component characteristics, please refer to the Appendix.

The following sizing specifications and details were obtained using the SAM:

- Modules per string: 12
- Strings in parallel: 6,6,5
- Subarray: 3
- Number of modules: 204
- Inverter maximum input voltage: 800V
- Voc at reference conditions (V): 772.8
- Number of inverters: 5
- Total module area (m^2): 332.7

For more information on component characteristics, please refer to the Appendix.

Generation Analysis

The generation analysis provides information on the cost savings and energy production achieved with the installed PV system, including demand coverage, efficiency, and cost-effectiveness.

- Total electricity bill with system: $1,591.01
- Total electricity bill without system: $10,833.95
- Total electricity consumption (kWh/yr): 105,151
- Total electricity use without system (kWh/yr): 9,718 (9.4%)
- Total AC energy (kWh/yr): 95,431
- Total installed cost: $157,500.00
- Total installed cost per capacity: $2.5/Wdc

Tables

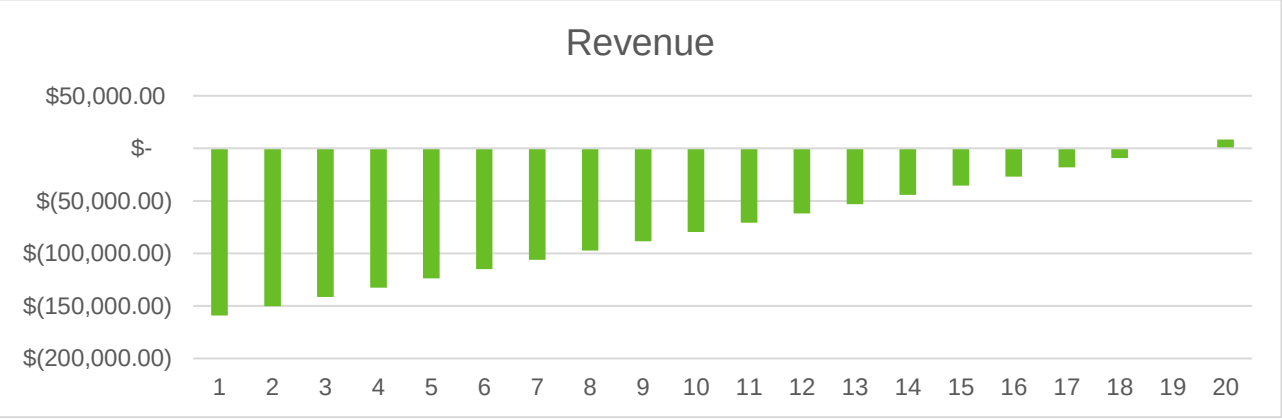
Table 10: Generation Analysis Data

	AC energy (year 1) (kWh/mo)	DC energy (kWh/mo)	Electricity use without system (kWh/mo)	Electricity bill with system ($/mo)	Electricity bill without system ($/mo)
Jan	6816.93	7072.19	4696	36	435.388
Feb	6356.52	6608.52	4942	36	474.406
Mar	8294.85	8619.76	4486	36	449.275
Apr	9270.2	9631.88	4723	36	453.67
May	9487.06	9863.65	5340	36	520.658
Jun	9530	9914.37	8865	36	834.915
Jul	9382.99	9761.41	20573	169.99	2062.72
Aug	8807.12	9161.24	21357	587.84	2154.16
Sep	8234.67	8564.41	13803	435.29	1345.75
Oct	7199.67	7488.28	5871	36	571.777
Nov	6638.36	6897.23	4403	36	443.872
Dec	5413.44	5632.43	6091	36	584.224

Table 11: Levelized Cost of Energy (LCOE)

Years	LCOE
1	1.65
5	0.3300
10	0.1650
15	0.1100
20	0.0825

Table 12: Revenue for First 20 Years



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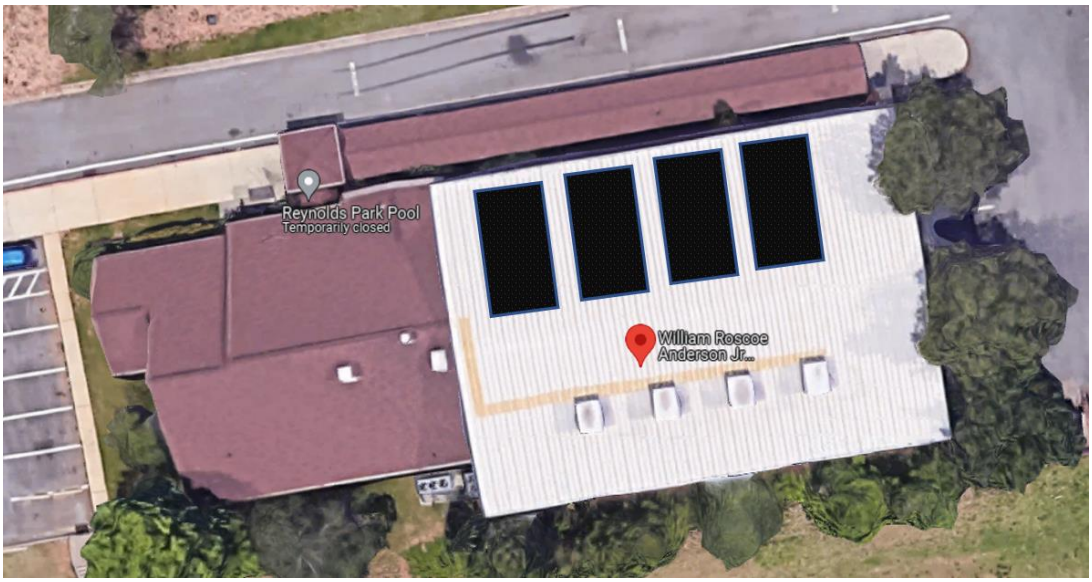


Figure 4: Reynolds Park – Image from Google Maps

Figure 4 illustrates a possible layout for the solar system at Reynolds Park.

Sedge Garden

The analysis for Sedge Garden indicates that it is a good option for solar PV installation. With a calculated system size of 98 kW, the available area of approximately 376 m² reduces the maximum system size to 72 kW, representing a 26.5% reduction. The feasibility study indicates that a solar installation will cover at least 68.6% of the building's electricity consumption.

Photovoltaic Sizing / SAM Analysis

The following information details the component specifications and PV sizing, obtained using the SAM. The PV modules selected for this system are the SunPower SPR-E19-310, which is a 310-watt panel, paired with the SunPower SPR-12000-3 [480] inverter, offering a maximum power output of 12.2 kW. For further information on component characteristics, please refer to the Appendix.

The following sizing specifications and details were obtained using the SAM:

- Modules per string: 15,15,12,12
- Strings in parallel: 5,4,4,4
- Subarray: 4
- Number of modules: 231
- Inverter maximum input voltage: 800V
- Voc at reference conditions (V): 966, 772.8
- Number of inverters: 6
- Total module area (m^2): 376.8

For more information on component characteristics, please refer to the Appendix.

Generation Analysis

The generation analysis provides information on the cost savings and energy production achieved with the installed PV system, including demand coverage, efficiency, and cost-effectiveness.

- Total electricity bill with system: $7,660.52
- Total electricity bill without system: $16,492.40
- Total electricity consumption (kWh/yr): 157,749
- Total electricity use without system (kWh/yr): 49,470 (31.4%)
- Total AC energy (kWh/yr): 108,277
- Total installed cost: $179,000.00
- Total installed cost per capacity: $2.5/Wdc

Tables

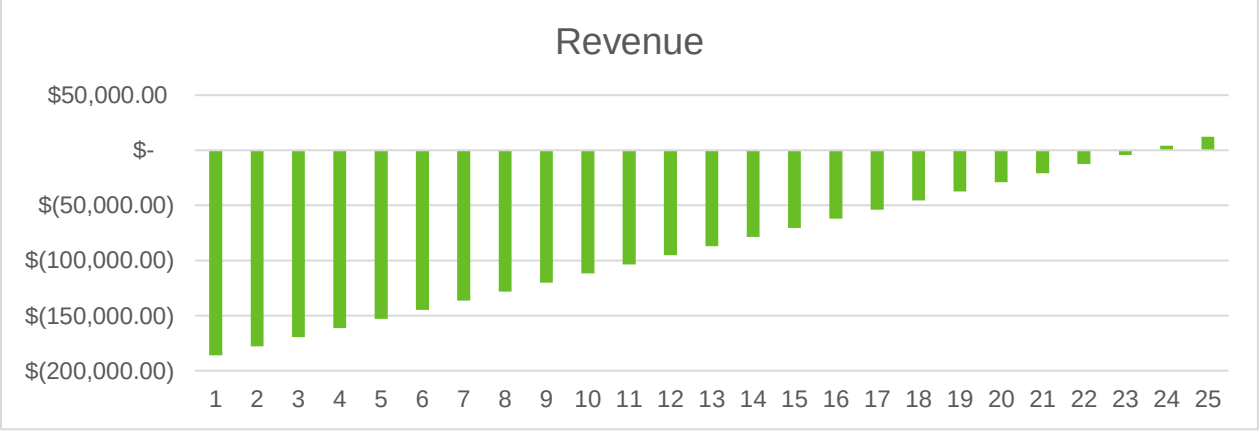
Table 13: Generation Analysis Data

	AC energy (year 1) (kWh/mo)	DC energy (kWh/mo)	Electricity use without system (kWh/mo)	Electricity bill with system ($/mo)	Electricity bill without system ($/mo)
Jan	7728.75	8000.21	24752	2823.16	3268.08
Feb	7213.44	7483.18	18251	1616.37	2031.61
Mar	9414.18	9760.61	11267	142.722	903.332
Apr	10520.5	10906.7	10885	132.834	989.743
May	10764.4	11169.1	7465	36	519.516
Jun	10812.6	11226.6	9564	36	745.003
Jul	10644.8	11053.4	12443	118.78	1189.4
Aug	9991.32	10373.8	15092	360.444	1503.07
Sep	9343.27	9697.94	13845	630.553	1434.66
Oct	8169.24	8479.38	10307	159.135	807.72
Nov	7532.74	7810.1	11066	274.804	857.805
Dec	6142.34	6377.9	12811	844.677	1198.22

Table 14: Levelized Cost of Energy (LCOE)

Years	LCOE
1	1.65
5	0.3306
10	0.1653
15	0.1102
25	0.0661

Table 15: Revenue for First 25 Years



Figures

Figure 5: Sedge Garden – Image from Google Maps

Figure 5 illustrates a possible layout for the solar system at Sedge Garden.

Salem Lake Marina

The analysis for Salem Lake Marina indicates that it is not a viable option for solar PV installation. With a calculated system size of 90 kW, the available area of approximately 160 m² reduces the maximum system size to 31 kW, representing a 65.5% reduction. The feasibility study indicates that a solar installation will cover at least 32.3% of the building's electricity consumption.

Photovoltaic Sizing / SAM Analysis

The following information details the component specifications and PV sizing, obtained using the SAM. The PV modules selected for this system are the SunPower SPR-E19-310, which is a 310-watt panel, paired with the SunPower SPR-15000-3 [480] inverter, offering a maximum power output of 15.3 kW. For further information on component characteristics, please refer to the Appendix.

The following sizing specifications and details were obtained using the SAM:

- Modules per string: 10
- Strings in parallel: 3,3,2,2
- Subarray: 4
- Number of modules: 100
- Inverter maximum input voltage: 800V
- Voc at reference conditions (V): 644
- Number of inverters: 2
- Total module area (m^2): 163

For more information on component characteristics, please refer to the Appendix.

Generation Analysis

The generation analysis provides information on the cost savings and energy production achieved with the installed PV system, including demand coverage, efficiency, and cost-effectiveness.

- Total electricity bill with system: $11,339.17
- Total electricity bill without system: $14,569.64
- Total electricity consumption (kWh/yr): 144,265
- Total electricity use without system (kWh/yr): 97,574 (67.6%)
- Total AC energy (kWh/yr): 46,690
- Total installed cost: $77,500.00
- Total installed cost per capacity: $2.5/Wdc

Tables

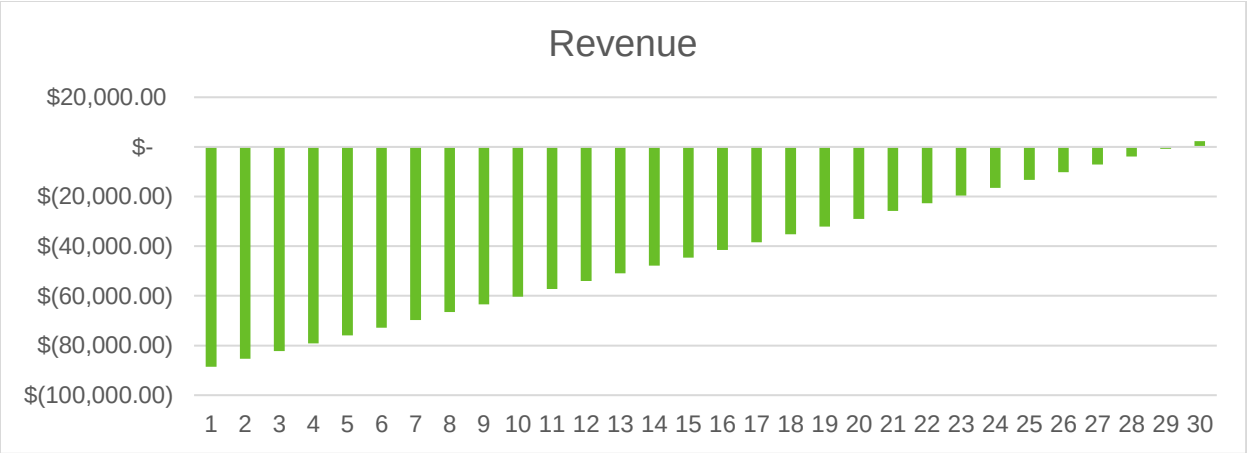
Table 16: Generation Analysis Data

	AC energy (year 1) (kWh/mo)	DC energy (kWh/mo)	Electricity use without system (kWh/mo)	Electricity bill with system ($/mo)	Electricity bill without system ($/mo)
Jan	3334.17	3466.76	18878	1958.44	2150.43
Feb	3110.16	3239.47	16587	1535.88	1714.97
Mar	4057.12	4225.37	9299	554.264	799.826
Apr	4533.92	4721.51	9214	556.64	852.964
May	4641.5	4835.12	7416	383.361	681.537
Jun	4662.88	4859.99	9332	535.549	829.196
Jul	4591.55	4785	10342	597.77	972.252
Aug	4309.88	4490.8	13330	936.273	1283.28
Sep	4028.84	4198.24	14490	1202.32	1491.97
Oct	3522.8	3670.73	6882	406.509	632.272
Nov	3247.84	3380.99	11289	746.639	984.952
Dec	2649.77	2761	17206	1581.86	1734.42

Table 17: Levelized Cost of Energy (LCOE)

Years	LCOE
1	1.66
5	0.3319
10	0.1659
15	0.1106
20	0.0829
30	0.0553

Table 18: Revenue for First 30 Years



Figures

Figure 6: Salem Lake Marina – Image from Google Maps

Figure 6 illustrates a possible layout for the solar system at Salem Lake Marina.

Johnson Municipal Center

The analysis for Johnson Municipal Center indicates that it is not a viable option for solar PV installation. With a calculated system size of 400 kW, the available area of approximately 2,035 m² reduces the maximum system size to 387 kW, representing a 3% reduction. The feasibility study indicates that a solar installation will cover at least 57.7% of the building's electricity consumption.

Photovoltaic Sizing / SAM Analysis

The following information details the component specifications and PV sizing, obtained using the SAM. The PV modules selected for this system are the SunPower SPR-E19-310, which is a 310-watt panel, paired with the SunPower SPR-12000-3 [480] inverter, offering a maximum power output of 12.2 kW. For further information on component characteristics, please refer to the Appendix.

The following sizing specifications and details were obtained using the SAM:

- Modules per string: 26
- Strings in parallel: 12
- Subarray: 4
- Number of modules: 1,248
- Inverter maximum input voltage: 800V
- Voc at reference conditions (V): 1,674.4
- Number of inverters: 28
- Total module area (m^2): 2,035.4

For more information on component characteristics, please refer to the Appendix.

Generation Analysis

The generation analysis provides information on the cost savings and energy production achieved with the installed PV system, including demand coverage, efficiency, and cost-effectiveness.

- Total electricity bill with system: $27,930.24
- Total electricity bill without system: $52,156.54
- Total electricity consumption (kWh/yr): 643,159
- Total electricity use without system (kWh/yr): 271,713 (42.2%)
- Total AC energy (kWh/yr): 371,446
- Total installed cost: $967,500.00
- Total installed cost per capacity: $2.5/Wdc

Tables

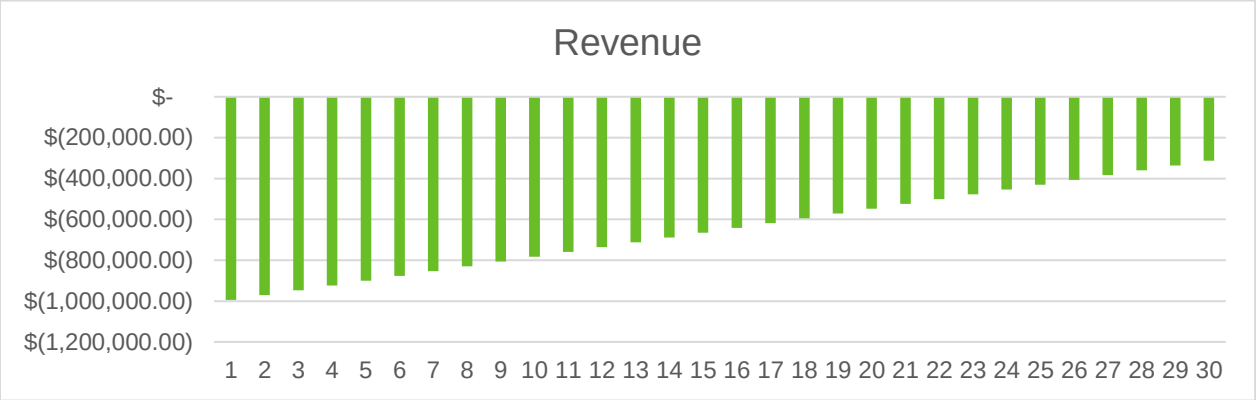
Table 19: Generation Analysis Data

	AC energy (year 1) (kWh/mo)	DC energy (kWh/mo)	Electricity use without system (kWh/mo)	Electricity bill with system ($/mo)	Electricity bill without system ($/mo)
Jan	24497.6	25434.9	51858	2453.75	3964.63
Feb	23364.5	24307.5	48025	2330.65	3756.46
Mar	30887	32077.7	52313	2298.76	4090.75
Apr	35743.1	37067.1	56214	2267.17	4525.39
May	37760.8	39167.9	52531	1513.6	4161.83
Jun	38807.8	40253.1	58081	1892.38	4636.89
Jul	38498.7	39933	60652	2441.53	4871.6
Aug	36147.4	37491.6	54822	2019.68	4266.55
Sep	33174.5	34408.8	59465	2702.51	4779.53
Oct	27908.4	28991.5	47941	2037.75	3774.6
Nov	24945.4	25911.4	49463	2378.43	3863.26
Dec	19711.3	20548.7	51795	2781.01	3946.83

Table 20: Levelized Cost of Energy (LCOE)

Years	LCOE
1	2.60
5	0.5209
10	0.2604
15	0.1736
20	0.1302
30	0.0868

Table 21: Revenue for First 30 Years



Figures

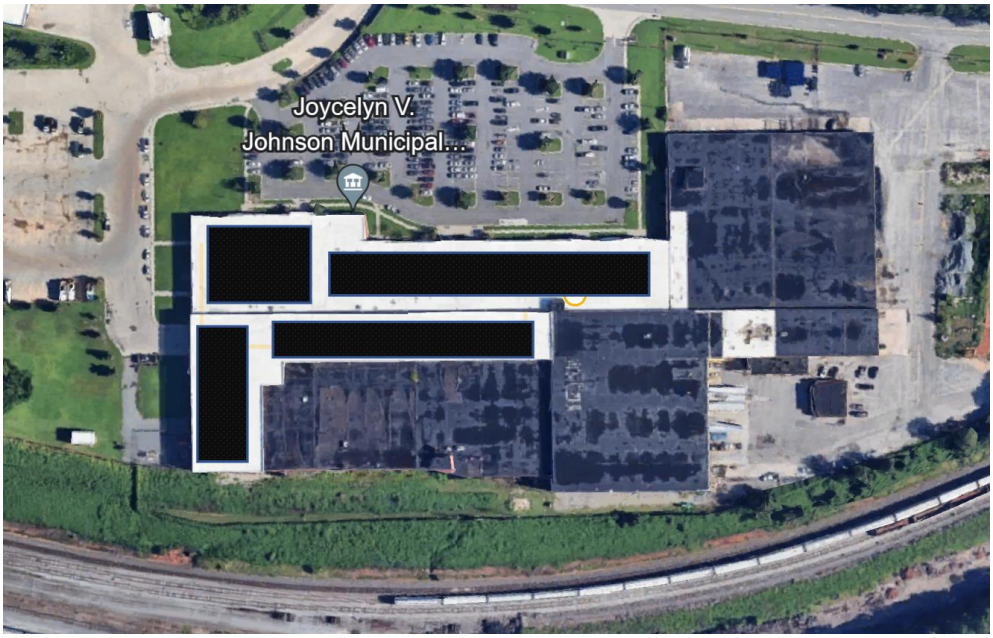


Figure 7: Johnson Municipal Center – Image from Google Maps

Figure 7 illustrates a possible layout for the solar system at Johnson Municipal Center.

Hanes Hosiery Center

The Hanes Hosiery Center analysis indicates that it is a good location for solar PV. With a calculated size of 83.6 kW and an approximate area of 335 m², the maximum PV size is limited to a 60 kW system (a 28% reduction). The feasibility study indicates that a solar PV installation will cover at least 67% of the building's electricity consumption.

Photovoltaic Sizing / SAM Analysis

The following information details the component specifications and PV sizing, obtained using the SAM. The PV modules selected for this system are the SunPower SPR-E19-310, which is a 310-watt panel, paired with the SunPower SPR-15000-3 [480] inverter, offering a maximum power output of 15.3 kW. For further information on component characteristics, please refer to the Appendix.

The following sizing specifications and details were obtained using the SAM:

- Modules per string: 12
- Strings in parallel: 4
- Subarray: 4
- Number of modules: 192
- Inverter maximum input voltage: 800V
- Voc at reference conditions (V): 772.8
- Number of inverters: 4
- Total module area (m^2): 313

For more information on component characteristics, please refer to the Appendix.

Generation Analysis

The generation analysis provides information on the cost savings and energy production achieved with the installed PV system, including demand coverage, efficiency, and cost-effectiveness.

- Total electricity bill with system: $5,077.29
- Total electricity bill without system: $10,045.54
- Total electricity consumption (kWh/yr): 99,744
- Total electricity use without system (kWh/yr): 44,466 (32.9%)
- Total AC energy (kWh/yr): 90,452
- Total installed cost: $148,750.00
- Total installed cost per capacity: $2.5/Wdc

Tables

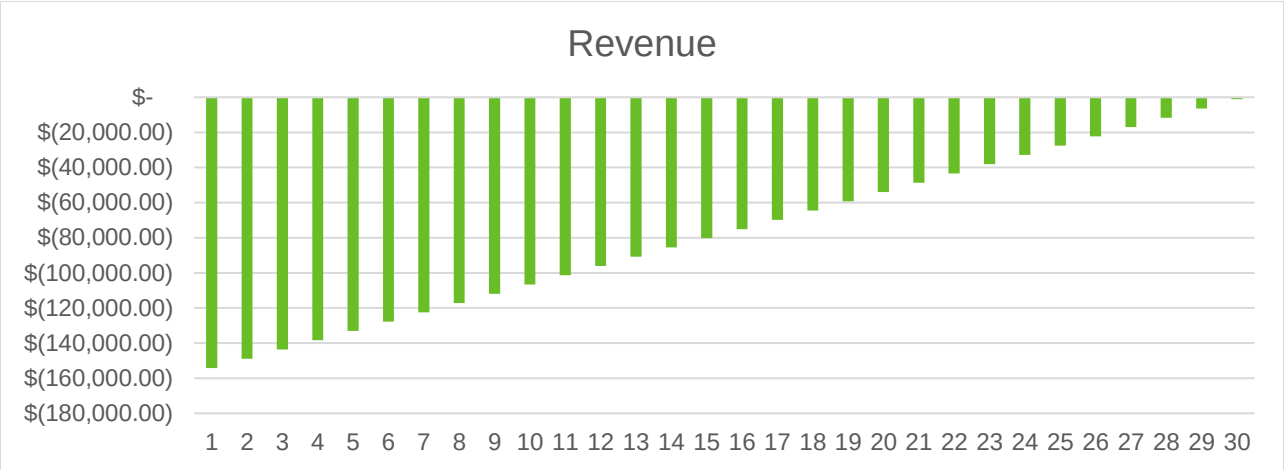
Table 22: Generation Analysis Data

	AC energy (year 1) (kWh/mo)	DC energy (kWh/mo)	Electricity use without system (kWh/mo)	Electricity bill with system ($/mo)	Electricity bill without system ($/mo)
Jan	6381.88	6613.97	8835.68	405.254	725.764
Feb	5994.04	6222.4	7634.88	222.727	568.294
Mar	7816.34	8112.56	7453.04	36	544.419
Apr	8792.42	9125.43	8654.96	36	635.93
May	8931	9274.64	8253.92	36	592.364
Jun	9014.43	9366.73	9377.08	36	670.514
Jul	8739.69	9082.35	15227.4	750.115	1274.84
Aug	8340.45	8664.46	18787	1075.19	1572.86
Sep	7742.84	8043.75	20529	1457.62	1848.42
Oct	7358.01	7638.73	13734.8	691.696	1052.97
Nov	6245.18	6480.3	9403.36	386.511	640.717
Dec	5096.41	5293.28	7028.44	255.865	535.127

Table 23: Levelized Cost of Energy (LCOE)

Years	LCOE
1	1.64
5	0.3289
10	0.1644
15	0.1096
20	0.0822
30	0.0548

Table 24: Revenue for First 30 Years



Figures

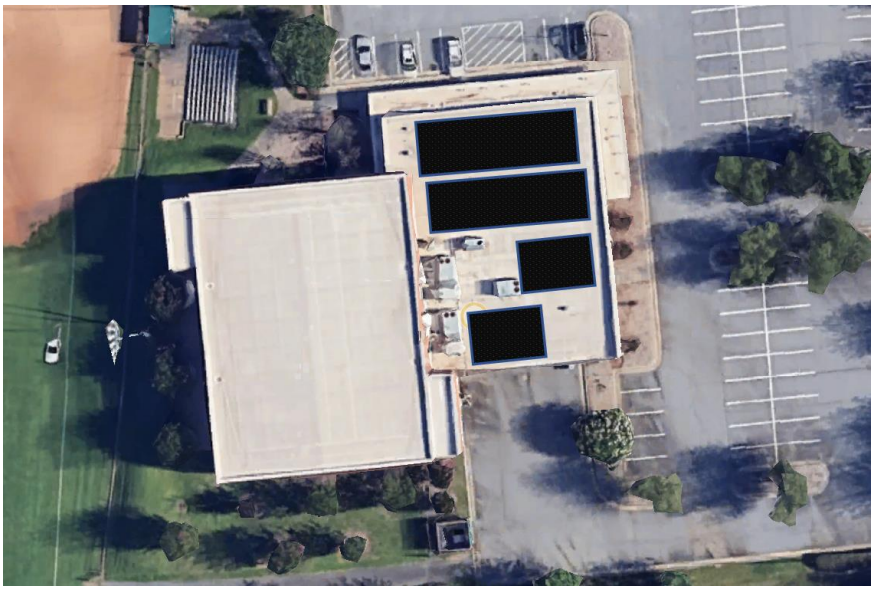


Figure 8: Hanes Hosiery Center – Image from Google Maps

Figure 8 illustrates a possible layout for the solar system at Hanes Hosiery Center.

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Carl Russell Center

The analysis for Carl Russell Center indicates that it is an excellent option for solar PV installation. With a calculated system size of 59 kW, the available area of approximately 300 m² reduces the maximum system size to 54.5 kW, representing an 8% system reduction. The feasibility study indicates that a solar installation will cover at least 86.5% of the building's electricity consumption.

Photovoltaic Sizing / SAM Analysis

The following information details the component specifications and PV sizing, obtained using the SAM. The PV modules selected for this system are the SunPower SPR-E19-310, which is a 310-watt panel, paired with the SunPower SPR-12000-3 [480] inverter, offering a maximum power output of 12.2 kW. For further information on component characteristics, please refer to the Appendix.

The following sizing specifications and details were obtained using the SAM:

- Modules per string: 10,10,12,12
- Strings in parallel: 4
- Subarray: 4
- Number of modules: 176
- Inverter maximum input voltage: 800V
- Voc at reference conditions (V): 644.0, 772.8
- Number of inverters: 4
- Total module area (m^2): 287

For more information on component characteristics, please refer to the Appendix.

Generation Analysis

The generation analysis provides information on the cost savings and energy production achieved with the installed PV system, including demand coverage, efficiency, and cost-effectiveness.

- Total electricity bill with system: $2,044.75
- Total electricity bill without system: $9,828.76
- Total electricity consumption (kWh/yr): 95,021
- Total electricity use without system (kWh/yr): 12,797 (13.5%)
- Total AC energy (kWh/yr): 82,223
- Total installed cost: $136,250.00
- Total installed cost per capacity: $2.5/Wdc

Tables

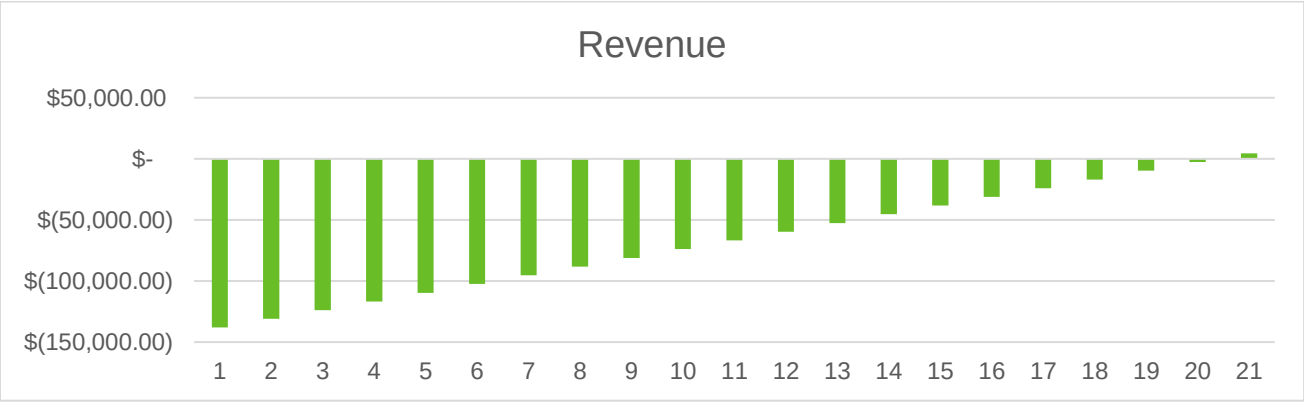
Table 25: Generation Analysis Data

	AC energy (year 1) (kWh/mo)	DC energy (kWh/mo)	Electricity use without system (kWh/mo)	Electricity bill with system ($/mo)	Electricity bill without system ($/mo)
Jan	5873.92	6101.49	5802	36	529.451
Feb	5477.8	5701.47	6110	68.272	578.02
Mar	7133.42	7436.65	5745	36	565.262
Apr	7983.36	8309.85	5	36	36.4422
May	8175.9	8509.82	4879	36	478.817
Jun	8213.18	8553.58	8145	36	762.255
Jul	8087.15	8421.61	10891	53.9911	1095.97
Aug	7590.98	7903.81	14223	547.254	1524.63
Sep	7096.62	7388.9	14692	783.734	1610.79
Oct	6204.75	6460.48	8284	155.765	786.175
Nov	5720.82	5950.55	4797	36	480.37
Dec	4665.91	4859.35	5813	48.8603	559.203

Table 26: Levelized Cost of Energy (LCOE)

Years	LCOE
1	1.65
5	0.3314
10	0.1657
15	0.1104
20	0.0828

Table 27: Revenue for First 21 Years



Figures

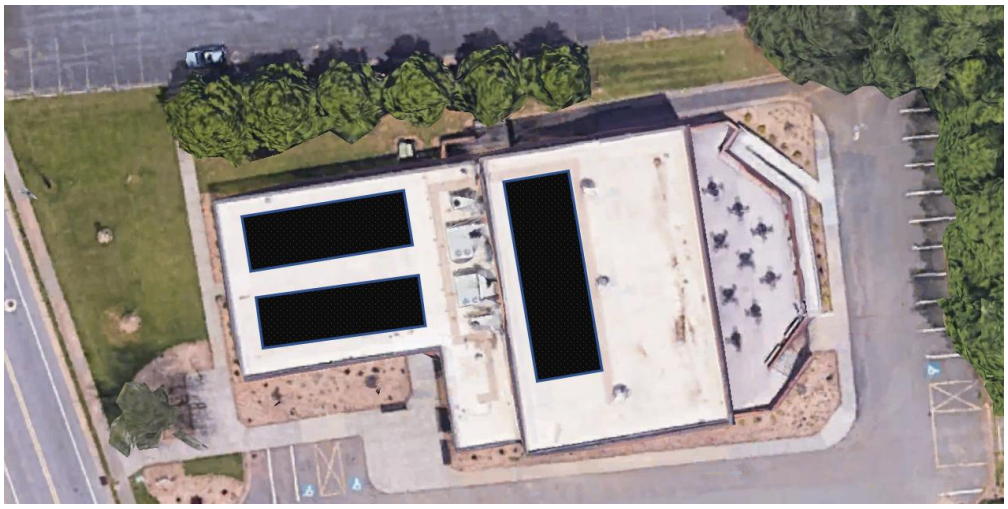


Figure 9: Carl Russel Center – Image from Google Maps

Figure 9 illustrates a possible layout of the solar system at Carl Russel Center.

Appendices

Module Characteristics

Name	SunPower SPR-E19-310
Manufacturer	SunPower
Technology	Mono-c-Si
I_sc_ref	6.05
V_oc_ref	64.4
Max Power	310

Inverter Characteristics:

Name	SunPower SPR-12000-3 [480]
Manufacturer	SunPower
Technology Type	Non-Hybrid
Max Current	18.2
Max Voltage	800
Max Power	12.2 kW
MPPT Inputs	1

Name	SunPower SPR-15000-3 [480]
Manufacturer	SunPower
Technology Type	Non-Hybrid
Max Current	22.7
Max Voltage	800
Max Power	15.3 kW
MPPT Inputs	1

References

U.S. Department of Energy, DOE Office of Indian Energy. (2015). *Levelized cost of energy (LCOE)*. Retrieved from https://www.energy.gov/sites/prod/files/2015/08/f25/LCOE.pdf

Go Green Solar. *Sizing solar systems: A step-by-step walkthrough*. Retrieved from https://www.gogreensolar.com/pages/sizing-solar-systems

Raman, M., & Darcy, M. (2024). *Solar panel calculator*. Omni Calculator. Retrieved from https://www.omnicalculator.com/ecology/solar-panel

National Renewable Energy Laboratory. *System advisor model (SAM)*. Retrieved from https://sam.nrel.gov/

U.S. Environmental Protection Agency. *Conducting site and economic renewable energy project feasibility assessments*. Retrieved from https://www.epa.gov/greenpower/conducting-site-and-economic-renewable-energy-project-feasibility-assessments

Reca, J., Torrente, C., López-Luque, R., & Martínez, J. (2016). Feasibility analysis of a standalone direct pumping photovoltaic system for irrigation in Mediterranean greenhouses. Renewable Energy, 85, 1143-1154.https://doi.org/10.1016/j.renene.2015.07.056

Schiavone, D. (2024). *Working on solar design and system sizing (FS-2023-0655)*. University of Maryland Extension.