Energy Efficiency Audit of Energizer's Battery Manufacturing Facility Asheboro, North Carolina

Authors: Delaney Buskard, Yinan Ding, Jack McCabe, and Jennifer Ronderos

MP Advisor: Timothy L. Johnson, Ph.D.

Client: Energizer Holdings, Inc

Degree:

Master's Project submitted in partial fulfillment of the requirements for the Master of Environmental Management degree in the Nicholas School of the Environment at Duke University

April 25, 2023

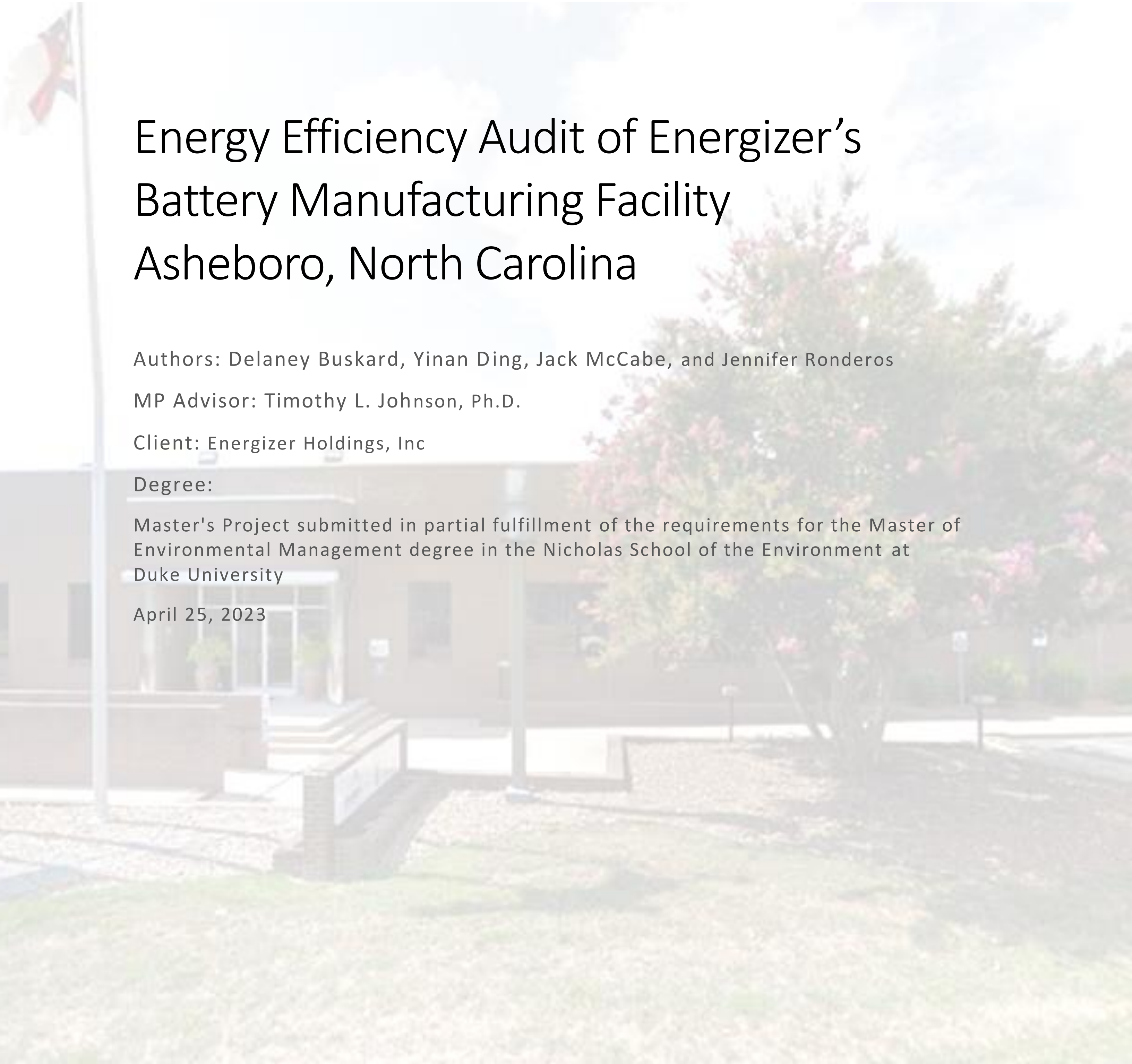


Table of Contents

Executive Summary

A team of Nicholas School of the Environment Master of Environmental Management (MEM) students were assigned to perform an energy efficiency audit at Energizer Holdings, Inc. (Energizer), Asheboro 2 Battery Manufacturing Facility located at 419 Art Bryan Drive, Asheboro, NC. The purpose of this master's project was to identify opportunities for energy savings, to identify high ROI (return on Investment) opportunities and contribute to Energizer's climate and energy goals by conducting this energy efficiency audit. These goals include reducing greenhouse gas (GHG) emissions companywide by 30% by 2030. The energy savings will lead to the GHG reductions and serve as a pilot for Energizer to improve the energy efficiency of all its domestic and international facilities. This energy audit was created by using Level 1 and 2 energy audit guidelines provided by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). We visited the facility multiple times to gather enough data to complete a bottom-up model of the facility's energy consumption. This bottom-up model aggregated the motor type, voltage, current, and horsepower of each of the motors or appliances in various areas across the Asheboro 2 Plant. The team used the model to estimate energy usage from major load sources. All the data was collected by using Energizer's Metrio system, Leaning2Lean smart manufacturing platform, physically counting lights, and estimating energy consumption from lighting and HVAC (Heating, Ventilating, and Air Conditioning). The team was not able to determine which motors should be replaced due to the motor analysis being outside of the scope of this project, as we do not have the expertise for this type of assessment. We recommend that Energizer conducts a formal observation on non-frequent usage appliances to determine if it's necessary to maintain any redundant appliances.

From our bottom-up model analysis we decided on the following recommendations that fulfill the purpose of the project for the facility:

- Convert the remaining portion of the facility to LED lighting.
- Implement lighting sensors in the warehouse and storage rooms.
- Conduct a separate further analysis of rooftop solar panel installation.
- Replace exterior windows with a minimum of double pane windows.

We were able to perform an analysis that indicates energy savings, GHG emissions savings within Scope 1 and 2, upfront cost, net present value (NPV) of project investments, payback period, and long-term savings. Energizer can save 50-90% of the warehouses energy usage by replacing all remainder fluorescent light with LED lighting. This includes setting up 50 lighting sensors in the warehouse and storage room. The team considered an opportunity for Energizer to implement solar panels and net metering. By installing a 1000 kW solar system, there's a potential of saving around $77,335-$110,333.3 USD per year. However, a further feasibility study and cost analysis must be conducted to justify the viability. Our last recommendation is to replace the windowpane glass with double pane glass because it will reduce heating and cooling costs by 44%. Each recommendation above is a project opportunity for Energizer to consider taking to meet their energy and climate goals.

As a team, we recommend that Energizer Holdings, Inc., implement the four project options that are found in the table below. These opportunities will reduce GHG emissions by 1.5 lbs. of CO2, which results in energy savings of around 1.9-2.2 million kWh per year, thus leading to saving about $167,432 per year. All the recommendations could be applied to their other facilities nationwide, unless otherwise noted.

Table 1. A Summary of Energy Conservation Recommendations

	Energy Savings Yearly (kWh)	Savings Yearly ($)	GHG Savings Yearly (lbs. of CO2)
1: 100% LED Lighting	**369,146**	**$19,639 - $28,018**	**315,620**
2: 50 Sensors in Warehouse and Storage Room	**123,411-316,549**	**$7,561 - $28,101**	**105,516 – 316,549**
3: Rooftop Solar	**145,3666**	**$77,335 - $110,333**	**1,242,885**
4: Double Pane Windows	**19,716**	**$979.79**	**1,881**
Total	**1,965,939- 2,159,077**	**$105,515- $167,432**	**1,560,386**

1. Introduction

This report documents the energy audit at Energizer's Asheboro battery manufacturing plant and the resulting energy efficiency recommendations to reduce energy use within the facility. Energizer's Battery Manufacturing Asheboro 2 Plant was built in 1969 and is located at 419 Art Bryan Drive, Asheboro, NC 27203. The building has 540,000 square feet and accommodates approximately 510 staff. The electricity supplier is Duke Energy, and the Natural Gas (NG) providers are Constellation and Piedmont Natural Gas. Ultimately, Energizer, depending on the results of the audit and the associated recommendations, will seek to conduct similar audits and energy efficiency upgrades at its other manufacturing facilities.

With the industrial manufacturing sector using more than 33% of the energy produced in the US, the potential impacts of reducing energy use through energy efficiency upgrades are significant[1] The benefits from reduced energy use are manifold and benefit both the company and the environment. Many facilities can reduce energy consumption by 10-20% with approximately 30% of those savings achieved without capital expense, thereby curtailing companies' expenditures on energy procurement[2]. Beyond the financial savings, companies seeking to reduce their climate impacts will also benefit from the results of an energy efficiency audit. With the energy sector globally responsible for 73.2% of greenhouse gas emissions, actions that companies take to reduce their energy consumption will also advance their climate goals through the reduction of their Scope 1 direct emissions and Scope 2 purchased energy emissions categories[3].

The potential for substantial cost savings, and Energizer's commitment to reduce its GHG emissions companywide by 30% by 2030[4], makes performing an energy audit a crucial strategy for Energizer to meet its reduction targets. Keeping in mind the dual goals of achieving cost savings and reducing GHG emissions through energy efficiency upgrades, our team conducted and documented the energy audit at the Asheboro facility so that it is easily

---

[1] https://www.energy.gov/sites/prod/files/2014/05/f15/energy-nam.pdf
[2] Ibid.
[3] https://ourworldindata.org/emissions-by-sector
[4] https://www.energizerholdings.com/docs/default-source/default-document-library/energizer-holdings-sustainability-report1.pdf

replicable at Energizer's other facilities. We provide Energizer with a financial analysis that includes the Net Present Value (NPV) and payback period of our recommendations along with the potential GHG reductions so that Energizer can quickly take actionable steps to reduce energy expenditures and GHG emissions. Based on the results of these analyses we outline energy efficiency recommendations primarily for replacing the 156 windows within the building and converting the remaining portion of the facility to LED lighting. We also note that only 2 of the facility's 17 bathrooms have been upgraded with water and energy efficient products. Analyzing the savings from installing these appliances is beyond the scope of our analysis, since we did not focus on water savings. Furthermore, although we received partial data for motors, light sensors, and Variable Frequency Devices (VFDs), ultimately, we determined that we lacked the expertise to make actionable recommendations on these components.

The remainder of the report is structured as follows: **Section 2**describes the methodology of our analysis as well as the physical characteristics of the manufacturing plant. **Section 3** provides results for the electricity and natural gas usage analysis, the analysis of the site's potential for solar photovoltaic panels on the rooftop, as well as the analysis of the heating and cooling costs associated with the buildings windows. **Section 4** provides recommendations along with the resulting energy savings and GHG emissions reductions associated with each recommendation. Also included in Section 3 is a financial analysis of each of the options explored. **Section 5** offers concluding thoughts as well as recommendations for further areas of inquiry.

2. Methodology

To achieve our project objectives, we conducted literature reviews on energy efficiency initiatives, GHG emission strategies, and sustainable practices to familiarize ourselves with key policies and tools that could be incorporated to address the research goals stated above. Additionally, relevant reports from previous studies done by Energizer, such as an energy study conducted in 2019, were reviewed[5]. We actively communicated with the client in terms of consolidating the project objectives and details and asked questions about the plant based on visual investigations, then compiled an energy efficiency inventory and assessment of energy

[5] ENERGY STUDY by Energizer, March 29, 2019

efficiency measures for operational systems in accordance with the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standards. ASHRAE is "a global society advancing human well-being through sustainable technology for the built environment."[6] Our inventory followed the ASHRAE level 1 and level 2 procedures[7]. Level 1 included a basic walk-through survey of the building to identify current energy use and areas where potentially inefficient energy use resided. Level 2 took Level 1 data for further analysis.

We collected and analyzed energy use and GHG emissions data to identify opportunities for improving energy efficiency and reducing GHG emissions. The focus is on Scope 1 and Scope 2 GHG emissions. Scope 1 includes any emissions that were generated from onsite energy use and company vehicles owned by Energizer.[8] Scope 2 emissions were from purchased electricity, transportation, steam, heat, or cooling. Transportation is exempt from the analysis as it is out of analyzing the target building. Additionally, we calculated the Energy Use Intensity (EUI) and other metrics of the target facility, which can be used to compare with other facilities of varied sizes, types, and geographical locations. EUI is a metric used to measure the energy efficiency of a building. It represents the amount of energy consumed per unit area over a specific period, and it is expressed in units of energy per square foot.[9] Eventually, we provided recommendations for the next step and created a roadmap for the implementation including a timeline, budget, and business case. Furthermore, a financial model was created in Microsoft Excel that incorporated considerations of the upfront cost, NPV, payback period, and long-term savings to seek opportunities in improving financial performance.

For data collection, we gained access to the Metrio system and Leading2Lean, acquired data from Energizer's staff, and collected the data during three onsite visits to Energizer's battery manufacturing facility in Asheboro, NC. The three on-site visits took place on November 4th, 2022, January 27th, 2023, and February 27th, 2023. Energizer's Metrio system is an internal system

---

[6] https://www.ashrae.org/about
[7] https://www.ashrae.org/File%20Library/Technical%20Resources/Technical%20FAQs/TC-07.06-FAQ-95.pdf
[8] https://www.energizerholdings.com/docs/default-source/default-document-library/energizer-holdings-sustainability-report1.pdf
[9] https://www.lawinsider.com/dictionary/energy-use-intensity-eui

that stores sustainability data for all of Energizer's facilities, including current and historical high-level energy use data and annual GHG emission data. Leading2Lean is a smart manufacturing platform that allows us to investigate the production and maintenance schedule. We acquired monthly electricity utility data from the fiscal year of 2017 to 2023, hourly data in the fiscal year 2023 provided by Duke Energy, and natural gas consumption data from the fiscal year of 2018 to 2022 provided by Constellation and Piedmont Natural Gas.

During three onsite visits, we investigated all the functional areas of the plant and collected necessary data such as the number, types, level of lighting, the model of some equipment, and the size and type of windows. We physically counted the number of lights in each room, investigated the types of light by looking at the information on light tubes, and measured the lighting condition using a phone app named Light Meter.[10] We also counted the number of windows and measured the size of each panel of the windows with a tape measure.

For utility data analysis, we used Microsoft Excel to examine the patterns, abnormalities, and extremes of the energy use in the facility, and created tables or charts to present the results. More specifically, the electricity use data was transferred from the monthly utility statement in PDF format into an Excel worksheet and was organized into a more granular form using pivot tables. We looked at the trend of monthly and yearly electricity use data, calculated the average hourly electricity use, and categorized consumption by seasons and months, weekdays and weekends, and hours of the day. Moreover, we conducted a similar analysis for natural gas data and calculated the EUI for the entire facility. In addition to the top-down electricity consumption analysis, we did a bottom-up analysis by creating a baseline model of each manufacturing line and room. The model breaks down power and electricity consumed by each piece of equipment and shows a total electricity usage that is calculated based on a summation of all equipment. A detailed calculation and model example is included in Appendix 4. We also used Microsoft Excel to create all the charts and tables included in this report. Maps are created using Google Earth Pro.

[10] https://apps.apple.com/us/app/lux-light-meter-pro/id1292598866

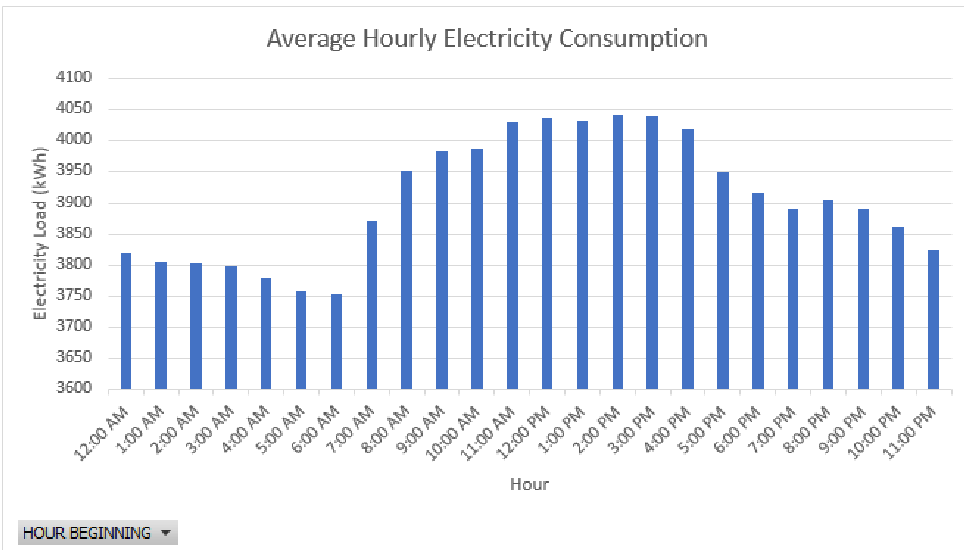
4. Results and Analysis

4.1. Electricity and Natural Gas Utility Analysis

4.1.1. Electricity Usage

We received daily electricity usage data dating back to 2018 with hourly data only being available for the past year. Based on this data, we analyzed several different usage profiles with the three highest variability usage profiles presented below.

Figure 1. Hourly Electricity Consumption 2022

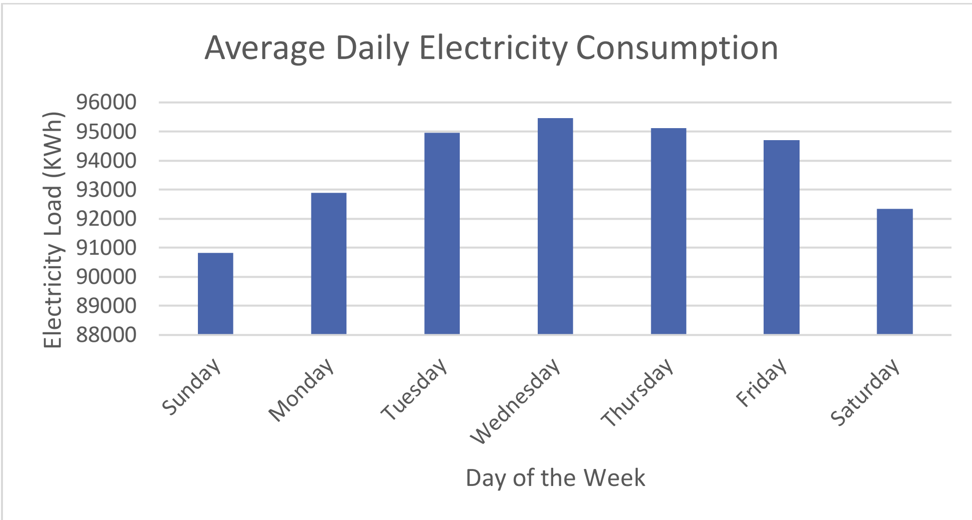


Hourly Electricity Consumption: Over a 24hr period the highest electricity consumption occurs over a 5-hour period from 11 AM to 4 PM, while the lowest usage occurs during the 5 AM to 6 AM period. We recommend that Energizer analyze what processes are being run during these time periods to determine if energy intensive processes can be evenly distributed throughout the day, which would result in a decreased electricity bill due to reduced demand charges. Demand charges are applied by utilities to customers maximum amount of power utilized within a given time period.[11] Utilities apply demand charges to encourage electricity consumers

[11] https://www.renewableenergyworld.com/wind-power/making-sense-of-demand-charges-what-are-they-and-how-do-they-work/#gref

to distribute their electricity usage over time, as utilities need to have enough generation and distribution capacity to meet electricity demand customers during periods of high usage[12].

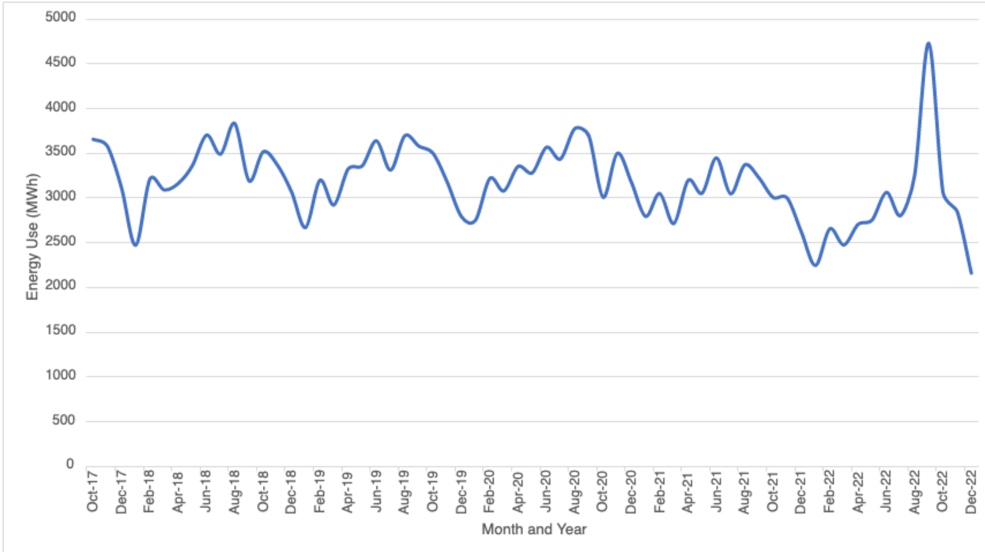
Figure 2. Daily Electricity Consumption 2022



Daily Electricity Consumption: Energy usage trends are clear over an hourly and daily timeframe. For daily trends, the highest usage occurs during the middle of the week on Wednesdays and Thursdays, while the lowest usage occurs on weekends. Like changes in hourly usage, distributing energy intensive activities evenly throughout the week would likely lead to reduced demand charges.

[12] Ibid.

Figure 3. Monthly Electricity Consumption Over Years 2017-2022

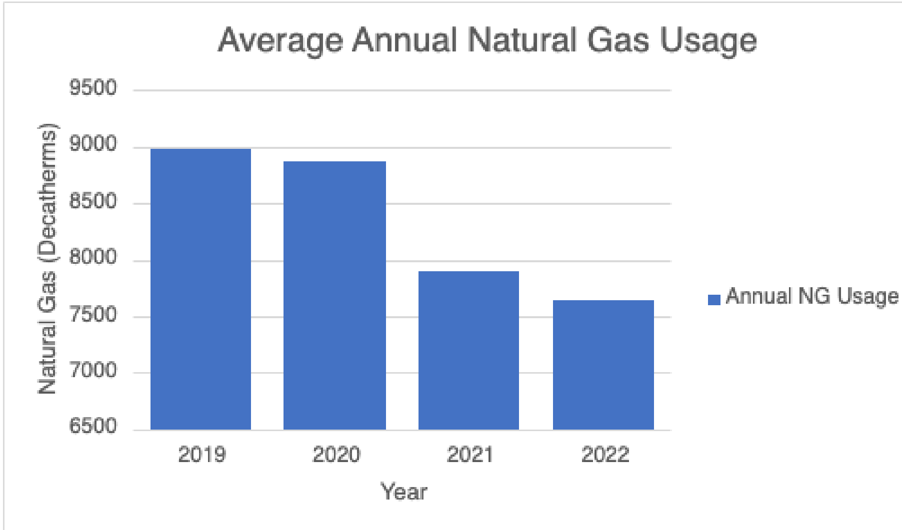


Monthly Electricity Consumption: The monthly energy consumption exhibits a seasonal variation and a noticeable abnormal peak in September 2022. Energy use is lowest during winter months throughout the 5-year period.

4.1.2. Natural Gas Usage

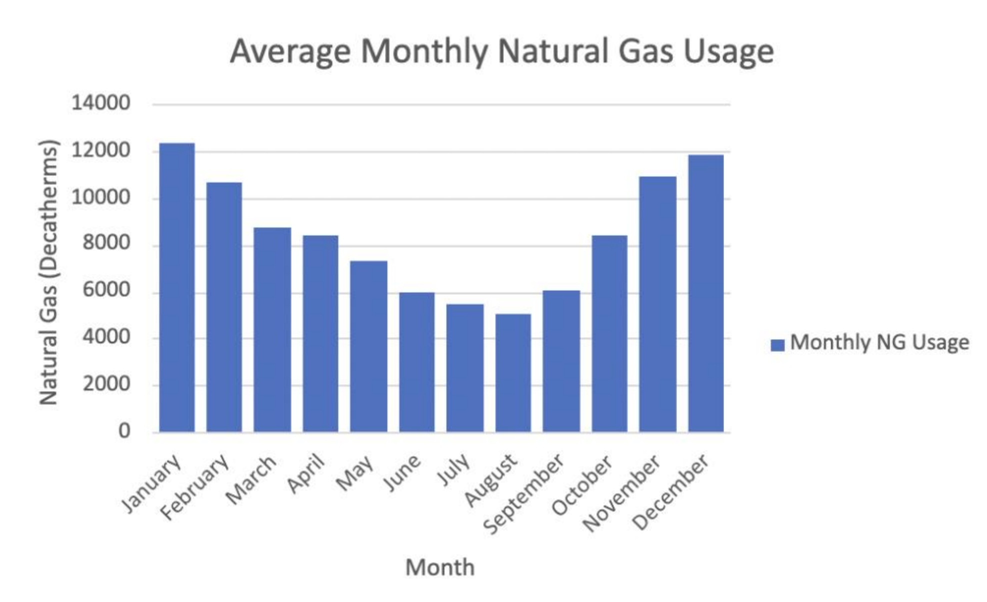
The Asheboro plant has three on-site natural gas generators and two providers of natural gas – Constellation and Piedmont Natural Gas. Natural gas usage, energy use intensity, and usage normalized for temperature were analyzed by combining the readings reported monthly from the two providers.

Figure 4. Average Annual Natural Gas Usage



Annual Natural Gas Usage: The combined natural gas readings exhibit trends on both an annual and monthly or seasonal basis. Across the four-year period, we observe a general decrease in natural gas usage, measured in decatherms. This is because of Energizer's recent repairs of steam leaks, upgrades to a boiler and a burner, and a lowering of production of D batteries in Asheboro.

Figure 5. Average Monthly Natural Gas Usage

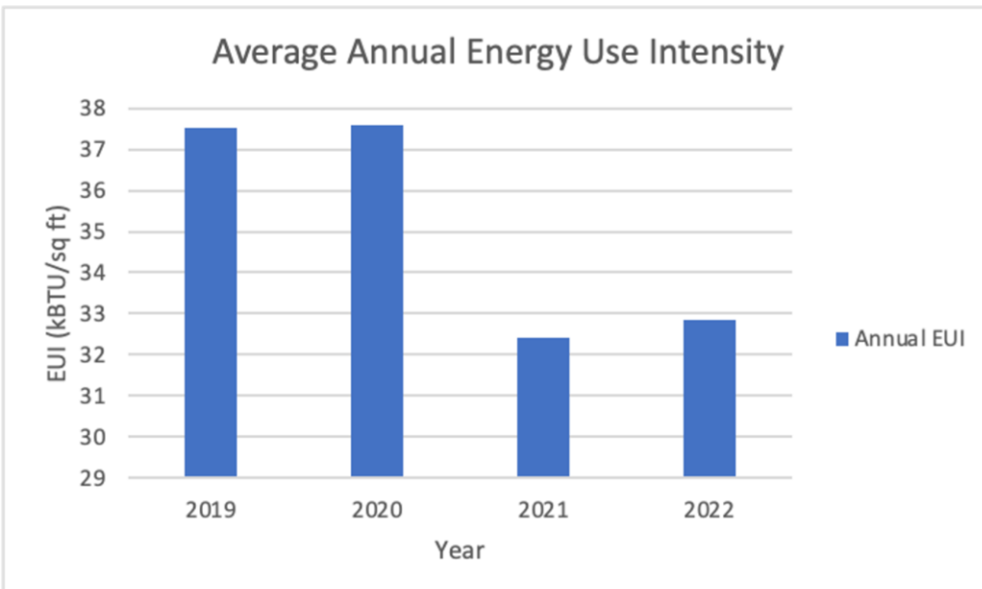


Monthly Natural Gas Usage: Over the four years observed (2019-2022), we see consistent variation by month. On a monthly basis, we see a seasonal change with the winter months providing readings that were higher than the spring and summer months.

4.1.3. Energy Use Intensity

EUI, which is the ratio of energy (thousand British Thermal Units) to building size (square feet), was the building and operations energy usage metric that was analyzed for the Asheboro 2 Plant. Specifically, we analyzed site EUI, which is reflected in the utility bills from Duke Energy, Constellation, and Piedmont Natural Gas.

Figure 6. Average Annual Energy Use Intensity



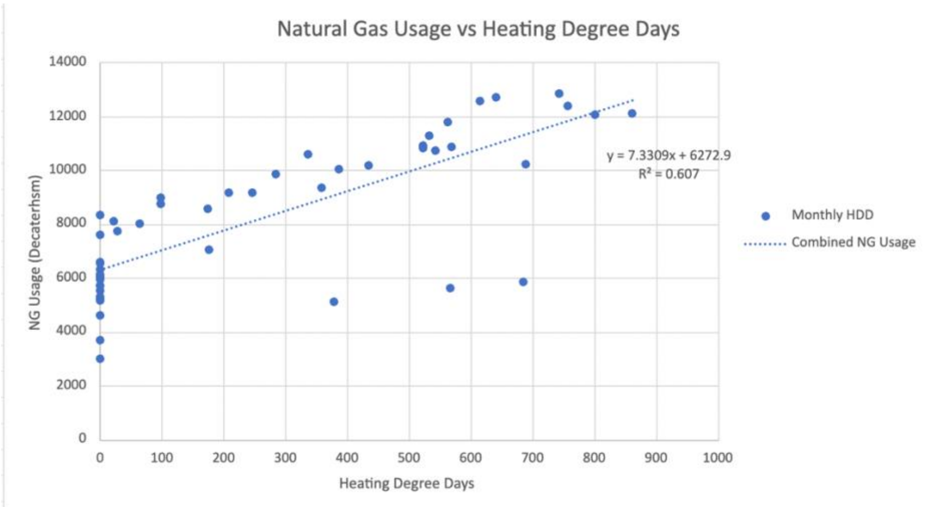
Annual EUI: From a combined analysis of natural gas and electricity EUI, we observe a relative decrease in EUI, with a large jump between 2020 and 2021. Benchmarked against the Department of Energy's Building Performance Database,[13] we observe that the EUI in all four years measured is lower than most other commercial facilities in North Carolina, with square footage between 500,000 and 600,000. Because of this, we did not target natural gas usage in

[13] https://bpd.lbl.gov/

our energy efficiency recommendations because the Asheboro 2 Plant is doing quite well compared to its peers.

4.1.4. Heating Degree Days

Figure 7. Natural Gas Usage Normalized for Monthly Heating Degree Days



To get a better understanding of the trends in natural gas usage, the monthly readings were normalized by heating degree days (HDD). One HDD is the difference between the daily average temperature and 65° F (where the average is below 65° F), which is designated as a "comfortable" temperature in which a model building will maintain a comfortable indoor temperature without additional heating or cooling.[14] Based on the monthly HDD, we observe a strong correlation between HDD and natural gas usage. However, the linear equation estimated based on the recorded data could aid in future forecasting for natural gas needs. Additionally, we note that even when there are 0 HDDs, NG use is continued, likely indicating that the on-site natural gas generation powers other ongoing operations.

---

14 https://www.weather.gov/key/climate_heat_cool#:~:text=Degree%20days%20are%20based%20on,two)%20and%2065%C2%B0F.

4.2. Bottom-up Energy Use Model

Table 2. Summary of Total Power and Energy Usage by Motor Line/Area of Asheboro Plant 2 for One Year

Line/Area	Number of Appliances/Motors	Total Power (kW)	Total Energy (kWh)
2A Ring Mold Line	117	85.5	748,564.8
3A Raw Cell Line	188	95.2	834,382.8
E91-92 Finishing Line	61	18.9	82,917.3
Main Breakroom	15	7.2	23,331.5
Small Parts Breakroom	6	5.2	6,165.4
Finishing Breakroom	10	6.8	20,095.6
Ring Molding Breakroom	11	7.2	23,331.5
Facilities	81	3,383.6	29,640,476.2
Total	**489**	**3,609.5**	**31,379,265.1**

We aggregated the motor type, voltage, current, and horsepower of each of the motors or appliances in various areas across the Asheboro 2 Plant. This bottom-up model does not include the energy loads from lighting in the Asheboro 2 Plant. From this information, we were able to estimate the approximate energy usage from each major load source. Energy usage was obtained by multiplying voltage, current, quantity, and number of operating hours for each type of motor or appliance, and converted to kilowatt hours, as shown in Appendix 4. Some of the motors have Variable Frequency Drive controls, however, it was assumed that each motor in the 2A Ring Mold and 3A Raw Cell lines and facilities ran at a constant level for 24 hours a day, 7 days a week, for the purpose of this project. It was assumed that each motor in the E91-92 Finishing line ran for 12 hours, 7 days a week. From the analysis of the motors in the three lines and the facilities, we observe that even though the motors that drive the facilities utilize the most energy, even though it has relatively few motors. We recommend estimating the age of the motors to determine if the older motors are less energy efficient, as well as compiling a more exact operating and maintenance schedule to get a more exact estimate of energy usage.

Additionally, this comparative analysis does not account for the 2A Collector, 3A Ring Mold, or the 3A Collector Assembly lines, nor does it include lighting usage, which will be discussed in the following section. Given our time and resources constraints, we were not able to determine which motors specifically should be replaced to improve energy efficiency.

The breakrooms contain only appliances – varying counts of coffee machines, ice machines, reach-in coolers, sandwich presses, and vending machines. Usage was approximated, as shown in Appendix 5, based on the combined 360 full-time employees and 150 temporary employees, and the average American's consumption. Coffee was averaged at three cups per day per person, the microwave was assumed to be used by everyone for two minutes per day, and the sandwich press was assumed to be used by everyone for five minutes per day. Though this may be an overestimation, we recommend a more formal observation of usage to remove redundant appliances if they are not used frequently.

5. Energy Conservation Recommendations

5.1. Lighting and Sensors

Existing Condition:

The client mentioned that most of the lights were upgraded to LED lights in a previous retrofit, which aligns with our study findings. Our statistics reveal that 93.2% of the lights are LED light tubes and 6.39% are fluorescent light tubes. Also, there are approximately 78 solar tubes installed in the warehouse to support lighting during daytime. Solar tubes utilize reflective tubes to channel natural light from the roof into interior spaces, providing illumination without the use of electricity. However, the amount of lighting provided by solar tubes is affected by the current weather conditions and they do not provide lighting at night. While the results indicate the presence of occupancy sensors in some rooms, we were unable to investigate their exact number and locations due to time constraints and a shortage of personnel.

The lighting levels for most of the working and break rooms in the facility were found to fall between 70-230 lux. The meeting room had a higher value of between 250-350 lux, whereas the hot room and mixing rooms had lower values of 30-100 lux. For general working areas, it is recommended to maintain a light level between 100-150 lux, 150 lux for warehouses, and 250 lux for office spaces[15]. Overall, these values fall within the typical illuminance levels for their respective room types.

---

[15] https://www.engineeringtoolbox.com/light-level-rooms-d_708.html

Table 3. Number and Types of the Light Bulbs in Energizer's Facility

Number and Types of the Light Bulbs (Estimate)			
Light Bulb Type	Room	Count	Sum
Fluorescent	Lobby	8	1204 (6.39%)
	Women's Restrooms (8)	458	
	Men's Restrooms (8)	458	
	Office Rooms	280	
LED	Machine Lights	6000	17568 (93.20%)
	Meeting Room	84	
	Break Rooms	435	
	Ring Mold Rooms	2029	
	Labs	198	
	Mechanical Rooms	168	
	Finishing Room*	1320	
	Mixing Blending Room	738	
	Can Washer Room	390	
	Storage Room*	654	
	Hot Room	56	
	Nail Room	2712	
	Raw Cell Rooms	1344	
	Press Room	96	
	Molding Room	606	
	Hallway	218	
	Warehouse	520	
Solar Tubes	Warehouse	78	78 (0.41%)
Total			18850
Rooms that are marked with an asterisk (*) are equipped with sensors.			

Recommendation:

Our recommendation is to replace all the existing fluorescent lights with energy-efficient LED lights and install additional occupancy sensors in the warehouse and storage room, where the occupancy rate is low. By installing occupancy sensors, the lighting can be automatically adjusted based on the presence of workers in the area, which can help reduce unnecessary energy waste. According to the U.S. Department of Energy, having occupancy sensors in the warehouse may save 50-90% of the energy and it is recommended to use horizontally mounted hallway or corner sensors[16]. Assuming the cost for each sensor is $100[17] and 50 sensors are needed, the total cost is $5000. The payback period for installing an additional 50 sensors ranges

[16] https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Wireless-Sensors-Guidance.pdf
[17] https://www.amazon.com/Sensor-Switch-Hallway-Occupancy-Voltage/dp/B003MT5FDI

from 0.18 to 0.65 years, depending on the percentage of electricity saved. Other assumptions made for this analysis are the percentage of savings, CO_2 production in lb. per kWh, and electricity prices.

Table 4. Electricity Savings and CO2 Reduction from Installing Occupancy Sensors in Warehouse and Storage Room

Energy and CO2 Reduction From Installing Occupancy Sensors			
Number of lights	1174.00		
Types of lights	LED		
Power of one light (W)	40.00		
Cost of one sensor ($)	100.00		
Number of Sensors Needed	50.00		
Total Cost ($)	5000.00		
hours/year	8760.00		
Electricity Consumption without Sensors (kWh/year)	411369.6		
Percentage of Savings	30%	50%	90%
Electricity Consumption with Sensors (kWh/year)	287958.72	205684.80	41136.96
Electricity Savings (kwh/year)	**123410.88**	**205684.80**	**370232.64**
CO2 production in lb/kWh	0.86		
CO2 reduction in lb/year	**105516.30**	**175860.50**	**316548.91**
lb to ton conversion rate	0.00045		
CO2 reduction in t/year	**47.86**	**79.77**	**143.58**
Electricity Price ($/kwh)	0.06	0.05	0.08
Financial Savings ($/yr)	**7651.47**	**10942.43**	**28100.66**
Payback	**0.65**	**0.46**	**0.18**

Furthermore, switching to LED lights will result in a significant reduction in energy costs and maintenance expenses since LED lights are known for their longevity and low power consumption. For example, an 8 ft 40 W LED light tube can provide 50,000 averaged rated hours (about 5.7 years) of 5500 lumens[18]. However, an 8 ft 75 W fluorescent light tube can provide

[18] https://www.gordonelectricsupply.com/p/Satco-S29925-40-Watt-8-Foot-T8-Led-5000K-Recessed-Double-Contact-Base-50000-Average-Rated-Hours-5500-Lumens-Type-B-Ballast/6941538?gclid=CjwKCAjwzuqgBhAcEiwAdj5dRmA57n9jgGjGZptnOO6ZuK-PcpWDKpJkdP3poUSYdv_nLQrKGQ2hcBoC_qIQAvD_BwE

12,000 hours (about 1.37 years) of 4500 lumens[19]. From the energy efficiency standpoint, an LED light can provide 137.5 lumens per watt, while a fluorescent light provides 60 lumens per Watt. Therefore, in this case, LED light is 56% more efficient than fluorescent light. Moreover, to meet the same lifespan of a LED light, at least 4 fluorescent lights are needed, which adds up to a cost of $40 and 38% more expensive than using LED light (Table 5).

Table 5. Electricity Saving and CO2 Reduction from Replacing Fluorescent Lights with LED Lights

	LED Light Tube	Fluorescent Light Tube
Power (W)	40.00	75.00
Lifespan (hour)	50000.00	12000.00
Lifespan (year)	5.71	1.37
Number of Fluorescent Lights needed to reach the same lifespan of a LED	4.17	
Lumens	5500.00	4500.00
Number of lights	1204.00	1204.00
hours/year	8760.00	8760.00
Cost of each light tube	29.00	11.00
Savings on Fluorescent placement during LED lifespan ($)	84447.22	
Electricity usage assuming operating 24/7 (kwh/year)	421881.60	791028.00
Electricity saved by replacing Fluorescent with LED (kwh/year)	**369146.40**	
CO2 production in lb/kWh	0.86	
CO2 reduction in lb/year	**315620.17**	
lb to ton conversion rate	0.00045	
CO2 reduction in t/year	**143.16**	

If the plant replaces all 1204 fluorescent lights, it could save around 369,146 kWh of energy per year, resulting in financial savings of between $19,639 and $28,018[20]. The payback period for this investment is estimated to be between 1.25 and 1.53 years (Table 6).

[19] https://www.1000bulbs.com/product/152897/PHILIPS-372821.html?gclid=CjwKCAjwzuqgBhAcEiwAdj5dRmH9GW6oTW0f74Rh2egah9WNcvfQ-5bftvJ-oJjn6YPAv4ni-mbNJhoCndoQAvD_BwE
[20] https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a

Table 6. Estimated Financial Savings from Replacing Fluorescent Lights with LED Lights

	Average electricity price of 2022 at Energizer's plant	EIA's average electricity price in January 2022	EIA's average electricity price in January 2023
Electricity Price ($/kwh)	0.06	0.05	0.08
Financial Savings ($/yr)	22887.08	19638.59	28018.21
Total Cost	34916.00	34916.00	34916.00
Payback	**1.53**	**1.78**	**1.25**

The numbers can vary based on the different lights used, the cost of each light bulb, and assumptions on electricity price per kWh. Overall, this upgrade will provide a more sustainable and cost-effective solution for lighting in the plant.

5.2. Windows

Existing Condition:

According to sources at the plant and through direct observation, there are 156 windows covering the exterior of the plant. Based on our inquiry, we were unable to determine the exact age of the windows. Nevertheless, through our investigations we determined that windows on the property appear to be all single paned. By switching to double paned, or even higher efficiency windows, there will be heating and cooling cost savings.

Recommendation:

We estimate that replacing the windowpane glass with double pane glass will reduce heating and cooling costs by 44% and will cost approximately $10,028.44 for a low cost ($6/Sq Ft) estimate replacement $15,042.66 for a medium cost estimate ($9/Sq Ft), and $20,056.88 for a high cost ($12/Sq Ft) estimate, with a payback period of 10.24, 15.35, and 20.47 years, respectively. Therefore, Energizer should proceed with bidding for replacing exterior windows with a minimum of double-pane windows. Electricity and natural gas savings, annual heating, and cooling savings, as well as emissions reductions from those savings are presented in the tables below.

Table 7. Electricity Usage and Scope 2 Emissions for Window Type

Electricity Usage and Scope 2 Emissions Reduction from Changing Window Type			
Single pane Electricity Demand	**Double Pane Electricity Demand**	**Electricity % Reduction**	**Scope 2 % Reduction**
3478 kWh/yr.	1932 kWh/yr.	-44.45	-0.003
Single Pane Scope 2 Emissions	**Double Pane Scope 2 Emissions**		
16047.99176 $MTCO_2$ e	16047.46751 $MTCO_2$ e		

Table 8. Natural Gas Usage and Scope 1 Emissions for Window Type

Natural Gas Usage and Scope 1 Emissions Reduction from Changing Window Type			
Single Pane NG Demand	**Double Pane NG Demand**	**NG % Reduction**	**Scope 1 % Reduction**
139 MMBTU/yr.	77 MMBTU/yr.	-44.60	-0.009
Single Pane Scope 1 Emissions	**Double Pane Scope 1 Emissions**		
3599.479 $MTCO_2$ e	3599.15 $MTCO_2$ e		

5.3. Potential for Rooftop Solar Installations and Net Metering

The state of North Carolina has set a target of reducing 70% greenhouse gas emissions below 2005 levels by 2030 and achieving carbon neutrality by 2050 through its clean energy plan[21]. Consequently, there is significant regulatory backing for the implementation of renewable energy sources. In this regard, our team investigated the viability of installing solar panels on the rooftop of Energizer's Battery Manufacturing Asheboro 2 Plant to offset electricity consumption, reduce operational costs, and use cleaner energy.

[21] https://deq.nc.gov/energy-climate/climate-change/nc-climate-change-interagency-council/climate-change-clean-energy-plans-and-progress/clean-energy-plan

Figure 8. Map of Energizer's Leased Land and Target Building from Bird's Eye View

Figure 9. Proposed Rooftop Area for Solar Panel Installation on Energizer's Building

The concept of net metering allows for the transfer of renewable energy generated by a customer-owned generator, such as solar panels, onto the grid to offset costs. After conducting thorough research on regulatory incentives and net metering rules, we discovered that commercial solar projects are eligible for a 30% Federal Tax Credit[22]. Additionally, Duke Energy offers a one-time rebate of 30 cents per watt of commercial solar installed, with a maximum cap

[22] https://www.energy.gov/eere/solar/homeowners-guide-federal-tax-credit-solar-photovoltaics

of $30,000[23]. Customer-owned photovoltaic systems are limited to a maximum nameplate capacity of 1,000 kW in North Carolina[24].

To determine the potential electricity generation at the Asheboro 2 Plant, we employed the PVWatts Calculator offered by the National Renewable Energy Laboratory (NREL) as an initial analysis[25]. The results indicate that the location has the potential to generate 1,453,666.21 kWh of electricity annually. A detailed monthly generation estimate, and assumptions made is included in Table 9.

Table 9. Monthly Estimate of Electricity Generated from a Potential Rooftop Solar System

Monthly estimate of solar power generation from a 1000 kW rooftop solar project at Energizer's Asheboro facility			
Month	**Daily Average POA Irradiance (kWh/m2/day)**	**DC Array Output (kWh)**	**AC System Output (kWh)**
January	3.94	107469.33	102305.98
Feburary	4.39	104926.87	98902.31
March	5.05	131010.65	122151.20
April	5.89	143400.88	134246.60
May	6.08	150887.42	142214.25
June	6.54	151743.10	144741.89
July	6.15	146237.18	139520.56
August	5.97	142473.48	135991.02
September	5.58	131860.92	125487.33
October	5.07	127344.48	121344.58
November	4.22	106755.98	101853.44
December	3.30	89032.80	84907.05
Total Output			**1,453,666.21**
The result was generated using EREL's PVWatts Calculator. The assumptions made include a DC System Size (kW) of 1000, a Standard Module, a Fixed and Open Rack Array, an Array Tilt (deg) of 20, an Array Azimuth (deg) of 180, System Losses (%) of 14, a DC to AC Ratio of 1.4, and an Inverter Efficiency (%) of 96. This result is based on the Energizer's Battery Manufacturing facility in Asheboro, NC. Any changes made to the above assumptions could lead to a different result.			

[23] https://p-cd.duke-energy.com/-/media/pdfs/for-your-home/2023-nc-solar-rebate-dec-dep-program.pdf?rev=104b50010e864b299bf9c559fb1c1361&_gl=1*c10fta*_ga*MjEwMTQ1MDE3Ny4xNjc3Mjc2MjU3*_ga_HB58MJRNTY*MTY3OTg3OTA3NC4xMi4wLjE2Nzk4NzkxMTEuMC4wLjA.&_ga=2.21368955.1934516837.1679879075-2101450177.1677276257&_gac=1.83963243.1679246109.CjwKCAjw5dqgBhBNEiwA7PryaFSy_T3HsXEq9tZm3v70hCj_PUpJ3zo2YTsIlJTGbqcT3vQe3Qp_ExoC5F4QAvD_BwE

[24] https://www.ncleg.net/Sessions/2017/Bills/House/PDF/H589v5.pdf

[25] https://pvwatts.nrel.gov/

Based on the electricity usage data in Fiscal Year of 2023, the proposed 1000 kW PV system can provide an estimate of 4.19% of the annual electricity consumption. Assuming the cost of the proposed PV system has an average cost of $1.45 per watt[26], the financial saving could range from $77335 to $110333.3 each year, varying with electricity price. The estimated payback period for installing the system ranges from 13 to 19 years (Table 10). This also contributes to a reduction of 1,242,885 pounds (536.76 tons) of Carbon Dioxide emissions, based on EIA's estimate of 0.855 pounds of Carbon Dioxide emissions per kWh[27].

[26] Commercial Solar Panels: Costs, Benefits & Best Installers (solarreviews.com)
[27] https://www.eia.gov/tools/faqs/faq.php?id=74&t=11

Table 10. Estimated Electricity Savings and CO2 Emission Reduction of Proposed PV System

Estimated Electricity Savings and CO2 Emission Reduction			
Capacity (kw)	1000		
Capacity (w)	1000000		
Projected Annual PV Generation (kwh/year)	1453666.21		
CO2 production in lb/kWh	0.855		
CO2 reduction in lb/year	1242884.61		
lb to ton conversion rate	0.000453592		
CO2 reduction in t/year	**563.7625158**		
Cost ($/watt)	1.45		
Total Cost ($)	1450000.00		
Electricity Price ($/kwh)	0.062	0.0532	0.0759
Financial Savings ($/yr)	**90127.30502**	**77335.04**	**110333.3**
Payback Period	**16.09**	**18.75**	**13.14**

Additionally, although there seems to be enough rooftop space available to install a 1,000-kW solar system, the impact of such panels on existing equipment remains uncertain. As a result, it is necessary to conduct a further feasibility study and cost analysis to assess the viability of installing rooftop solar panels. If roof top solar system is not viable, solar canopy installed on parking lot is an alternative option.

6. Conclusion

Based on the totality of our analyses, we recommend that Energizer proceed with the solutions we outline above. We acknowledge that only the LED replacement recommendation meets the two-year payback period Energizer expects for capital investments, however, any meaningful reduction in energy usage and correspondingly, GHG emissions, will require a more strategic long-term view of the value of capital investments at Asheboro 2 Plant. In addition to the steps outlined above, we also recommend that Energizer's electrical engineers at the plant investigate which plant processes result in the most energy expenditure. While we attempted to do so, due to the nature of the data we received, as well as our lack of technical expertise, we believe a more in-depth assessment by individuals with more expertise could yield insights into additional ways to reduce expenses. For instance, by identifying energy intensive activities and then distributing them more evenly over the day and across the week, Energizer could substantially reduce its demand charges from Duke Energy. Overall, we strongly encourage Energizer to standardize data collection and storage procedures for energy usage within their facilities. With the termination of this project, we propose that Energizer conduct similar processes at all its domestic manufacturing facilities. Although these audits are time and expertise intensive, they have the potential to drive both significant savings and substantial GHG reductions.

7. Bibliography

1000 Bulbs. "Philips 37282-1 - F96T12/DX/ALTO - Single Pin T12 Bulbs - 75W - 6500K | 1000Bulbs.Com." *T12 Single Pin Linear Fluorescent Tubes*, https://www.1000bulbs.com/product/152897/PHILIPS-372821.html?gclid=CjwKCAjwzuqgBhAcEiwAdj5dRmH9GW6oTW0f74Rh2egah9WNcvfQ-5bftvJ-oJjn6YPAv4ni-mbNJhoCndoQAvD_BwE. Accessed 20 Apr. 2023.

About ASHRAE | Ashrae.Org. https://www.ashrae.org/about. Accessed 19 Apr. 2023.

Amazon.Com : Sensor Switch HW-13 PIR Hallway Sensor Motion Occupancy Sensor Low Voltage, White : Other Products : Electronics. https://www.amazon.com/Sensor-Switch-Hallway-Occupancy-Voltage/dp/B003MT5FDI. Accessed 19 Apr. 2023.

Apple. "Lux Light Meter Pro on the App Store." *App Store Preview*, https://apps.apple.com/us/app/lux-light-meter-pro/id1292598866. Accessed 20 Apr. 2023.

ASHRAE. *ASHRAE Technical FAQ*. 95, p. 2, https://www.ashrae.org/File%20Library/Technical%20Resources/Technical%20FAQs/TC-07.06-FAQ-95.pdf.

Better Buildings. *Fact Sheet | Wireless Sensors for Lighting Energy Savings*. Mar. 2022, p. 8, https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Wireless-Sensors-Guidance.pdf.

Brown, Gwendolyn. "Making Sense of Demand Charges: What Are They and How Do They Work?" *Renewable Energy World*, 6 June 2017, https://www.renewableenergyworld.com/wind-power/making-sense-of-demand-charges-what-are-they-and-how-do-they-work/#gref.

Duke Energy. *NC Solar Rebate Program*. Jan. 2023, p. 1, https://p-cd.duke-energy.com/-/media/pdfs/for-your-home/2023-nc-solar-rebate-dec-dep-program.pdf?rev=104b50010e864b299bf9c559fb1c1361&_gl=1*c10fta*_ga*MjEwMTQ1MDE3Ny4xNjc3Mjc2MjU3*_ga_HB58MJRNTY*MTY3OTg3OTA3NC4xMi4wLjE2Nzk4NzkxMTEuMC4wLjA.&_ga=2.21368955.1934516837.1679879075-.

Energizer Holdings, Inc. *Energy Study*. 29 Mar. 2019.

---. *Sustainability Report*. 2022, p. 35, https://www.energizerholdings.com/docs/default-source/default-document-library/energizer-holdings-sustainability-report1.pdf.

Gordon Electric Supply, Inc. *SATCO S29925 40 Watt 8 Foot T8 LED 5000K Recessed Double Contact Base 50000 Average Rated Hours 5500 Lumens Type B Ballast Bypass Double Ended Wiring | Gordon Electric Supply, Inc.* https://www.gordonelectricsupply.com/p/Satco-S29925-40-Watt-8-Foot-T8-Led-5000K-Recessed-Double-Contact-Base-50000-Average-Rated-Hours-5500-Lumens-Type-B-Ballast/6941538?gclid=Cj0KCQjwxYOiBhC9ARIsANiEIfYPGD7ObFPfaAwtM7JWpkz-a1jwYHBrcPTFd8Sb0HghnUyQSpRfEE0aAhiEEALw_wcB. Accessed 20 Apr. 2023.

House Bill 589 - Ratified Bill. 589, 2017, https://www.ncleg.net/Sessions/2017/Bills/House/PDF/H589v5.pdf.

Law Insider. “Energy Use Intensity (EUI Definition).” *Law Insider*, https://www.lawinsider.com/dictionary/energy-use-intensity-eui. Accessed 19 Apr. 2023.

National Association of Manufacturers. *Efficiency and Innovation in U.S. Manufacturing Energy Use*. 2014, p. 33, https://www.energy.gov/sites/prod/files/2014/05/f15/energy-nam.pdf.

National Renewable Energy Laboratory. “PVWatts Calculator.” *NREL’s PWAtts Calculator*, https://pvwatts.nrel.gov/. Accessed 20 Apr. 2023.

NC DEQ. *Clean Energy Plan*. https://www.deq.nc.gov/energy-climate/climate-change/nc-climate-change-interagency-council/climate-change-clean-energy-plans-and-progress/clean-energy-plan. Accessed 20 Apr. 2023.

Ritchie, Hannah, et al. “CO_2 and Greenhouse Gas Emissions.” *Our World in Data*, May 2020. *ourworldindata.org*, https://ourworldindata.org/emissions-by-sector.

Solar Reviews. “Commercial Solar Panels: Costs, Benefits & Best Installers.” *Solar Reviews*, 22 Sept. 2022, https://www.solarreviews.com/content/blog/installing-commercial-solar-panels.

The Engineering Toolbox. “Illuminance - Recommended Light Level.” *The Engineering Toolbox*, https://www.engineeringtoolbox.com/light-level-rooms-d_708.html. Accessed 19 Apr. 2023.

U. S. Department of Energy. *Building Performance Database*. https://bpd.lbl.gov/. Accessed 19 Apr. 2023.

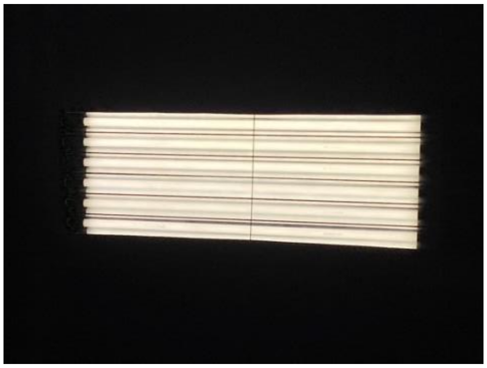
U. S. Department of Energy. “Homeowner’s Guide to the Federal Tax Credit for Solar Photovoltaics.” *Energy.Gov*, https://www.energy.gov/eere/solar/homeowners-guide-federal-tax-credit-solar-photovoltaics. Accessed 20 Apr. 2023.

US Department of Commerce, NOAA. *What Are Heating and Cooling Degree Days*. NOAA’s National Weather Service, https://www.weather.gov/key/climate_heat_cool. Accessed 19 Apr. 2023.

U.S. Energy Information Administration (EIA). *Electric Power Monthly*. https://www.eia.gov/electricity/monthly/epm_table_grapher.php. Accessed 20 Apr. 2023.

U.S. Energy Information Administration (EIA). “Frequently Asked Questions (FAQs).” *Frequently Asked Questions (FAQs)*, https://www.eia.gov/tools/faqs/faq.php. Accessed 20 Apr. 2023.

8. Appendices



Appendix 1. LED Light Tube in the Facility

Appendix 2. Solar Tubes in the Warehouse

Appendix 3. Florescent Light in Offices

Appendix 4: Sample Bottom-Up Model of Aggregate Energy Load (3A Raw Cell Line)

AREA	DESCRIPTION	MOTOR TYPE	VFD CONTROL	MOTOR VOLTAGE (V)	MOTOR CURRENT (A)	MOTOR HORSEPOWER (HP)	QUANTITY	TOTAL POWER (W)	TOTAL ENERGY (kWH)
ANODE PUMP	MAIN PUMP	3 PHASE	YES	460	1.4	3/4	7	4508	39490.08
RCAM	MAIN DRIVE	3 PHASE	YES	460	4.4	3	7	14168	124111.68
RCAM	INFEED CONVEYOR	3 PHASE		460	1.1	1/2	7	3542	31027.92
RCAM	CELL EXIT	3 PHASE		460	0.6		7	1932	16924.32
RCAM	TRACK BLOWER	3 PHASE		460	1.5		7	4830	42310.8
RCAM	COLLECTOR ELEVATOR	3 PHASE		460	0.8	1/3	7	2576	22565.76
RCAM	ROLLER FEED DRIVE	3 PHASE		460	1.6		7	5152	45131.52
RCAM	ROLLER FEED BRUSH	1 PHASE		120	1.1		7	924	8094.24
CELL WASHER	MAIN DRIVE	3 PHASE	YES	460	1.1	1/2	7	3542	31027.92
CELL WASHER	PUMP	3 PHASE		460	2.1		7	6762	59235.12
CELL WASHER	EXIT CONVEYOR	3 PHASE		460	0.6		14	3864	33848.64
TRAY LOADER	EXIT CONVEYOR	3 PHASE		460	1.4	3/4	7	4508	39490.08
TRAY LOADER	STEPPER	STEPPER		2.31	4		7	64.68	566.5968
FILM FORMER	SERVOS	SERVO		230	0.5		8	920	8059.2
FILM FORMER	STEPPER	STEPPER		2.26	6.1		7	96.502	845.35752
FILM FORMER	MAIN DRIVE	3 PHASE	YES	460	1.4	3/4	15	9660	84621.6
ASPHALTER	MAIN DRIVE	3 PHASE		460	1.4	3/4	15	9660	84621.6
ASPHALTER	ROLLER FEED DRIVE	3 PHASE		460	1.6		15	11040	96710.4
ASPHALTER	ROLLER FEED BRUSH	1 PHASE		120	1.1		15	1980	17344.8
ASPHALTER	COLLECTOR ELEVATOR	3 PHASE		460	0.8	1/3	15	5520	48355.2

Appendix 5: Sample Bottom-Up Model of Aggregate Energy Load (Main Breakroom)

Equipment Name	Voltage (V)	Current (A)	Quantity	Power (W)	Energy (kWh)
Microwave			6	1000	17
Coffee Machine	115	12.9	1	1483.5	479.4332031
Ice Machine	115	11.5	1	1322.5	11585.1
Reach-in Cooler	115	3.14	2	722.2	6326.472
Sandwich Press	115	18	1	2070	87.975
Vending Machines	115	1.2	4	552	4835.52