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Discovering Energy Efficiency Opportunities in Asheville's Craft Brewing Industry

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Abstract

The purpose of this study is to analyze the potential impact of energy efficiency improvements at craft breweries in Asheville, North Carolina. Reducing energy consumption within a facility will in turn reduce its fossil fuel emissions. The Environmental Protection Agency promotes energy efficiency within industrial facilities through its Energy Star program. This study utilized an Energy Star checklist designed specifically to identify energy efficiency improvements within a microbrewery. Four microbreweries of various sizes participated in this study. In order to analyze the potential impact of energy efficiency improvements made within each facility, an evaluation of each microbreweries' historical energy consumption data was conducted. Energy consumption data allows the determination of potential environmental and economic impacts of energy efficiency improvements made within a brewery. Energy efficiency opportunities were discovered within all participating microbreweries. Efficiency improvements that yield the most potential savings are found in the refrigeration and steam generation systems. Results show that annual savings at each brewery ranged from $252 to $19,349, based on this review. Each brewery could save on average 69,084 kWh of electricity, ranging from 6,235 kWh to 43,464 kWh, 5,248 Therms of natural gas, ranging from 71 Therms to 18,220 Therms, and avoid emitting 77,334 lbs of carbon dioxide, ranging from 2,686 lb to 232,720 lb per year.

1. Introduction

Sustainability and craft brewing are two identities found within Asheville, NC. Asheville's sustainability values are backed by its Municipal Climate Action Plan (MCAP), which enables the city to enhance energy efficiency, support sustainability for businesses and improve infrastructure to facilitate inclusive sustainability (City of Asheville, 2023). Asheville's craft brewing industry is home to over 35 brewing businesses, contributes $111 million in labor income to brewing activity jobs, as well as $934 million towards the economy as of 2016 (Economic Development Coalition, 2017). In 2009, Asheville won the title "Beer City USA" because it holds more craft breweries per capita than any other U.S. city (Economic Development Coalition, 2017).

Although brewing beer is beneficial to the local economy and community, it is an energy-intensive process which inevitably leads to high fossil fuel consumption. The reduction of energy consumption and greenhouse gas (GHG) emissions is steadily advocated for in the brewing industry (Olajire, 2012). An analysis of energy efficiency potential at craft breweries was performed in Latvia, where the brewing industry is saturated with small and medium sized breweries. The total production capacity of small and medium breweries in Latvia is much lower than that of large breweries, but they are highly valued in terms of beer quality, similar to what is found in Asheville, NC. From an environmental perspective, energy efficiency opportunities at small and medium sized breweries are lower than those at large-scale breweries. This is due to lower economies of scale, batch processes, non-continuous operations and other local conditions such as climate, production technology, product mix, different bottling technologies, brewery size, years of operation, geographical location, applied processes and equipment (Kubule, 2016). As competition is a driving force in business, including breweries, benchmarking energy efficiency in breweries can motivate investments for economically and environmentally beneficial improvements and innovation. Due to increasing energy prices, a brewery may be keen to identify the full potential energy efficiency measures it could produce. Energy efficiency improvements will require upfront investments, which may be reflected through an increased price per unit of beer. An analysis of consumers' willingness to pay found that on average, consumers are willing to pay more for a beer produced with more sustainable practices. The results highlight that consumers may choose sustainable commodities such as organic food because of its potential to protect human health, whereas those that are willing to pay a premium for sustainable beer are instead paying merely for the environmental aspects of the commodity. (Carley and Yahng, 2018).

In order to recognize the value of energy efficiency projects within the brewing industry, it is important to understand the basic process of how beer is brewed. At a brewery, steam is generated by boiling water in one or more natural gas boilers depending on the size of the brewery. Steam is used during the mashing process, where grain starches are heated and converted into fermentable sugars. The product of mashing is a sugar-rich liquid known as wort. Breweries then boil the wort, and use steam to drive off unwanted volatile compounds such as dimethyl sulfide (DMS), which is largely undesirable in beer as it gives it a 'sweetcorn' taste (GrainFather, 2021). Steam also plays a crucial role in maintaining high sanitation levels within a brewery. Electricity is used for various filtration procedures throughout the brewing process. During mashing, once the starches from grain are converted into fermentable sugars, the grain is no longer needed and filtered out. After the wort is boiled, it is placed in a hydrocyclone which is used to separate and remove hop resins and coagulated proteins from the liquid. After the brewing process, the brewery uses electricity to package its beer into glass bottles, cans or kegs. The beer is then stored at around 45 degrees fahrenheit in refrigerators within the facility before distribution. The packaging process and refrigeration are the main consumers of electricity within a brewery.

Data from the U.S. EPA shows that refrigeration, packaging, and compressed air consume 70% of U.S. breweries' electricity use, whereas the brewing process consumes 45% of U.S. breweries' natural gas use (Brewers Association, 2010). The total amount of electricity and natural gas usage within a brewery is depicted in *Figure 1.*

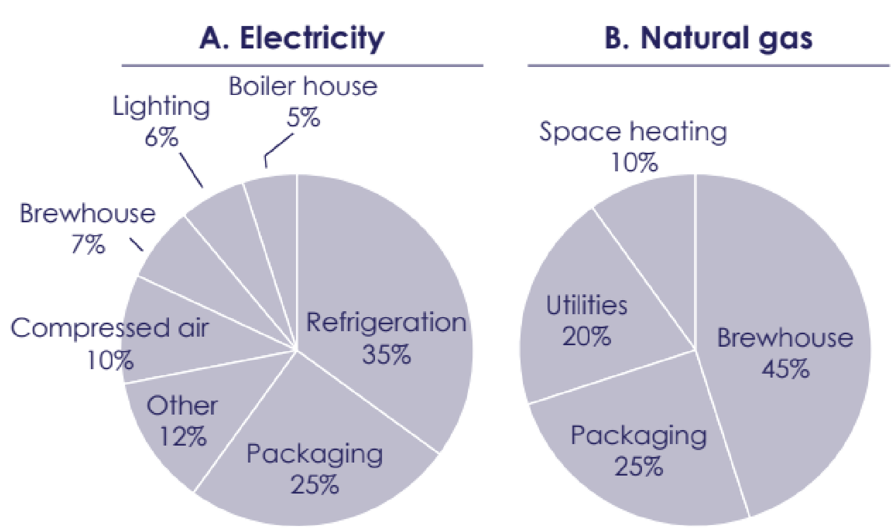

Figure 1. *Total electricity and natural gas usage in a brewery (Brewers Association, 2010)*

The Brewers Association's Manual on Energy Usage, GHG Reduction, Efficiency and Load Management along with The Reference Document on Best Available Techniques in the Food, Drink and Milk Industries (BREF) provides benchmarks for energy and resource consumption in beer production. They suggest breweries should consume approximately 12-22 kWh/bbl packaged and 1.3-1.5 Therms/bbl packaged (Brewers Association, 2010). As these benchmarks were established a decade ago and are based on data for large-scale breweries, they may not be relevant for current situations in small and medium sized breweries. This is again due to lower economies of scale, batch processes, non-continuous operations and other local conditions (Kubule, 2016).

This project focuses on four local microbreweries and their respective energy consumption, with the intent of identifying potential energy savings and reducing the resultant greenhouse gas emissions. This effort is part of a local community effort to encourage sustainable practices. Production levels (in barrels packaged per year) and facility size varied considerably in this study. The project determines the potential environmental and economic impacts of energy efficiency improvements made within each brewery as well as analyzes how size may affect their potential to reduce energy consumption.

2. Methods

2.1 Study Site Description

The four microbreweries that participated in this project were Wicked Weed Brewing, Hi-Wire Brewing, Cellarest Beer Project and The River Arts District (RAD) Brewing. The data collection was performed during production hours and before brewery taprooms were open to the public. The time spent collecting data at each site ranged from one to three days for two hours each day, depending on the size of the brewery. *Table 1* lists each of the four breweries that participated in this study, their location and the amount of beer they have the capacity to package in barrels (BBL) per year.

Name	**Address**	**Annual Capacity (BBL/year)**
Wicked Weed Brewing	145 Jacob Holm Way, Candler, NC 28715	105,000

Hi-Wire Brewing	2A Huntsman Pl, Asheville, NC 28803	35,000
The RAD Brewing	13 Mystery St, Asheville, NC 28801	300
Cellarest Beer Project	395 Haywood Rd, Asheville, NC 28806	200

Table 1. *Description of the four participating microbreweries*

2.2 Data Collection and Analysis

The project utilized the Environmental Protection Agency's (EPA) Energy Star Treasure Hunt (Energy Star, 2019) that is designed specifically for microbreweries to identify energy efficiency opportunities within their facilities. The treasure hunt contains a list of over 150 possible energy savings opportunities that are categorized by low-cost or capital investment upgrades. The project also used an infrared thermal camera to help identify heat energy leaks within different equipment throughout each brewery. A year's worth of energy consumption data (electricity and natural gas), barrels of beer brewed per year, as well as the amount of production hours per day and days per week are all required to accurately analyze the potential impacts of implementing energy efficiency upgrades. Waste Reduction Partners in Asheville used data from the U.S. EPA and NC Department of Air Quality to design an emissions calculator that allows easier quantification of pollutant emissions. This project utilized the emissions calculator to determine the amount of pollutant emissions that could be avoided by implementing each opportunity. The emissions calculator uses the amount of electricity (kWh) and natural gas (Therms) saved per year to quantify the amount of CO_2, SO_2, and NOx emissions that would be avoided annually.

By following the Energy Star Treasure Hunt checklist, my research team and I along with brewery staff began searching for energy efficiency opportunities within their facility. The Energy Star Treasure Hunt lists energy efficiency opportunities in sections that focus on different areas within a brewery, such as hot water and steam systems, chillers, refrigeration, motors, pumps and piping systems, compressed air, lighting and building envelope, all of which were used in this project. Considering that some participating breweries did not serve food, the Food Service Equipment section of the checklist was excluded from this project.

A year's worth of energy consumption data and barrels packaged per year is used to determine the amount of energy it takes for a brewery to brew one barrel of beer.

$$kWh\ or\ Therms\ per\ Bbl = 12\ Month\ Total\ Energy\ Consumption \div \#\ Bbl\ Packaged\ per\ Year$$

Electricity and natural gas providers use rates that vary depending on the amount of energy used, the time of day that the energy is consumed or the location of a facility. This project calculates energy unit costs in order to determine a fixed unit cost and easily determine the cost that each opportunity could save. The total cost used in this calculation includes base fees added by electricity or natural gas providers. The cost per kWh (or Therm) is determined by dividing the 12-month total of electricity and natural gas costs by the 12-month total of kWh or Therms consumed.

$$Cost\ per\ kWh\ or\ Therm = Total\ Cost \div Total\ Consumption$$

For each opportunity found, the reduction of electricity, natural gas, and cost as well as CO_2, SO_2, and NOx emissions that could be avoided was calculated. *Figure 1* shows the percentage of energy that each area within a brewery consumes. The percentage of energy consumption used in each calculation varies based on the area within a brewery that an opportunity is found. For example, if an opportunity was found within the refrigeration area of a brewery, it is assumed that 35% of their electricity consumption comes from that area.

$$kWh\ or\ Therms\ consumed\ by\ refrigeration = 35\% \times Total\ Electricity\ or\ Natural\ Gas\ Usage$$

In order to determine the energy use reduction impact of implementing an energy savings opportunity, an extensive analysis of each facility's energy usage must be carried out. Thorough measurement of energy consumption within each area of a brewery would require about a year’s worth of data collection. Considering this project collected data at the breweries for approximately two days each, the energy use reduction impact from each opportunity must be estimated. The reduction impact of each energy savings opportunity that this project identified is estimated based on previous energy audits performed at breweries by Waste Reduction Partners (WRP) of Asheville. Marshall Goers, an engineer at WRP assisted in these estimations. The estimated impact of an opportunity determines the amount of energy that could be saved by implementing it. The percentage of energy use reduction is estimated based on the expected impact of the opportunity on overall energy use, shown in *Table 2.*

Impact of Opportunity	**Range of Energy Use Reduction Impact (%)**
Slight	2-5
Medium	10-15
Substantial	15-20

Table 2. *Energy use reduction percentages used to estimate impacts of each opportunity*

In order to determine how much energy an opportunity could save, the percentage of energy use reduction impact is estimated. For example, if a substantial opportunity was discovered within the refrigeration area of a brewery, the energy use reduction impact may be estimated to be 17%. The amount of energy that opportunity could save can then be determined by multiplying the percentage of energy use reduction impact by the kWh or Therms consumed by the refrigeration area of the brewery, as shown in the calculation below.

$$kWh\ or\ Therms\ Saved = 17\%\ Reduction\ Impact \times kWh\ or\ Therms\ consumed\ by\ refrigeration$$

The energy costs saved by each opportunity can be calculated by multiplying the unit cost per kWh or Therm by the amount of kWh or Therms saved. Inputting the amount of kWh or Therms saved for each opportunity into the emissions calculator determined the amount of CO_2, SO_2, and NOx emissions that could be saved. It is important to note that the calculated CO_2 emissions that are avoided by implementing each energy savings opportunity are based on a brewery's consumption of energy and does not include the CO_2 that is produced from the fermentation process of brewing beer.

3. Results and Discussion

3.1 Wicked Weed Brewing

Wicked Weed is the largest brewery that participated in our project. Operating 24 hours per day during the week and around 150 hours per week, they have the capacity to package approximately 105,000 bbl per year at their Candler, NC production facility. At this facility, Wicked Weed uses approximately 2,282,369 kWh of electricity and 183,795 Therms of natural gas per year. This data allows us to determine that Wicked Weed uses 21.7 kWh/bbl of beer packaged and 1.8 Therms/bbl of beer packaged.

3.1.1 Energy Savings Opportunities

Energy efficiency opportunities that were discovered within Wicked Weed are quantifiable and allow the determination of energy and money saved as well as CO_2, SO_2, and NOx emissions that could be avoided per year if implemented. *Table 3* lists Wicked Weed's quantified energy efficiency opportunities. The opportunities that were identified within Wicked Weed's facility at their Candler, NC location reveals that Wicked Weed could reduce their electricity consumption by 27,388 kWh and save over $2,000 in utility costs per year by optimizing the usage of their fans in the production area. The opportunities that were identified in the refrigeration area of their facility could also save them over $1,300 in utility costs per year, but may require a higher implementation cost than optimizing the use of their fans. The insulation around Wicked Weed's condensate recovery tank could be improved and save energy, but the percentage of reduction impact for this opportunity is slight compared to similar opportunities identified in the other four participating breweries. This is because although their insulation could be improved, there is not as much damage/lack of insulation in this area of their brewery as there was in other breweries that participated.

Opportunity	Estimated Reduction Impact (%)	Electricity Saved (kWh)	Natural Gas Saved (Therms)	Cost Saved ($)	CO_2 Emissions Avoided (lb)	SO_2 Emissions Avoided (lb)	NOx Emissions Avoided (lb)
Improve insulation around condensate recovery tank	2	0	2,573	2,082	30,076	0.15	25.23
Improve sealing around refrigerated storage areas	1	7,988	0	677	6,929	3.55	4.46
Repair refrigerated storage area internal insulation damage	1	7,988	0	677	6,929	3.55	4.46
Determine number of fans used in production area and record wattage used. Consider a program that optimizes air	10	27,388	0	2,321	23,757	12.19	15.28

movement while minimizing electrical use							
Total		43,364	2,573	5,757	67,692	19.45	49.43

Table 3. *Opportunity summary for Wicked Weed*

3.1.2 Current Sustainable Practices

A year prior to participating in this project, Wicked Weed worked with Waste Reduction Partners in Asheville to conduct an energy survey and discover ways they can reduce their energy usage. Wicked Weed's sustainability team used what they discovered from the energy survey to create their own action log and prioritize reducing their energy usage. This prioritization of energy efficiency in their facility may have impacted the amount of energy savings opportunities that were identified during the data collection of our project.

3.2 Hi-Wire Brewing

Hi-Wire Brewing is the second largest participating microbrewery, operating around 70 hours per week, they have the capacity to package around 35,000 barrels per year. Hi-Wire's historical energy usage data indicates that they use approximately 352,914 kWh of electricity per year and 80,977 Therms of natural gas per year. Based on these data, Hi-Wire uses around 10 kWh of electricity and 2.3 Therms of natural gas per barrel of beer packaged.

3.2.1 Energy Savings Opportunities

Some energy efficiency opportunities that were discovered within Hi-Wire are quantifiable and allow the determination of energy and money saved, as well as greenhouse gas emissions that could be avoided per year if implemented. *Table 4* lists Hi-Wire's quantified energy efficiency opportunities. The energy savings opportunities within Hi-Wire's facility were discovered mainly where their hot water and steam systems needed insulation or existing insulation needed repair. These identified opportunities alone have the potential to significantly reduce Hi-Wire's consumption of natural gas by 12,754 Therms per year and save them approximately $18,000 in natural gas costs. The amount of insulation improvements that could be implemented at Hi-Wire were significantly greater than those identified at Wicked Weed, leading to a higher percentage of energy reduction impact. The reduction impact of the opportunity identified in Hi-Wire's compressed air systems is more significant than other electricity savings opportunities that were discovered because a leak detection system is not in place. Monitoring for and repairing leaks in compressed air pipes is an essential component of preventative maintenance and has the potential to reduce 5,294 kWh of electricity and save $504 in utility costs per year. At Hi-Wire, the refrigerator doors are left open for long periods of time to allow people to go in and out freely while working. Cool air is lost by leaving the refrigerator door open, and in order to maintain set temperatures, the refrigerator consumes more electricity. A Fastrax door is an insulated curtain type of device that is placed in the door of large industrial refrigerators that automatically opens and closes when someone enters or exits. The installation of a Fastrax door at Hi-Wire could reduce approximately 6,176 kWh of electricity and save $588 in utility costs per year. The replacement of poorly insulated chilled water lines within Hi-Wire's facility has the potential to reduce their energy consumption and save money annually, but the initial investment in this opportunity may be higher compared to other opportunities' initial investment costs.

Opportunity	**Estimated Reduction Impact (%)**	**Electricity Saved (kWh)**	**Natural Gas Saved (Therms)**	**Cost Saved ($)**	**CO_2 Emissions Avoided (lb)**	**SO_2 Emissions Avoided (lb)**	**NOX Emissions Avoided (lb)**
Insulate steam lines and repair steam leaks	35	0	12,754	12,027	149,082	0.75	125.07
Optimize the use of the condensate recovery system	15	0	5,466	5,154	63,892	0.32	53.60
Implement comprehensive compressed air leak detection system and/or perform preventative maintenance on compressors themselves	15	5,294	0	504	4,592	2.36	2.95
Install Fastrax door to reduce refrigerated storage area heat gain	5	6,176	0	588	5,357	2.75	3.45
Replace poorly insulated chilled water lines	6	7,411	0	706	6,429	3.30	4.14

Install automatic stop system on canning line	8	2,823	0	269	2,449	1.26	1.58
Turn off lights in taproom area when not in use/install motion sensor lighting	5	1,059	0	101	919	0.47	0.59
Total		22,763	18,220	19,349	232,720	11.20	191.37

Table 4. *Quantified opportunity summary for Hi-Wire*

The impacts of other energy efficiency opportunities are not as easily quantified, but can still reduce energy consumption within a facility. *Table 5* reveals energy efficiency opportunities discovered within Hi-Wire that were not quantified.

Opportunity	**Description**
Heat loss at boiler	Insulation needed around maintenance access area on boiler
Air dryer next to boiler	Air dryer should be stored in a cooler, dryer area
Ceiling	Insulation needed on ceiling. Currently allowing chilled water lines below to absorb heat in the summer and causes building to lose heat during the winter
Preventative maintenance schedules	Improve regular preventative maintenance schedules for boiler, steam traps, chillers, motors, pumps and piping systems as well as compressed air systems

Table 5. *Non-quantifiable opportunity summary for Hi-Wire*

3.2.2 Current Sustainable Practices

Hi-Wire captures their CO_2 produced from fermentation and returns it back to a local farm. This is beneficial to farms as CO_2 is one of the most vital components of the growing process and also acts as a fumigant, allowing farms to reduce the use of pesticides. By capturing their CO_2, Hi-Wire is reducing the amount of emissions put into our atmosphere while simultaneously supporting a local farm.

3.3 The River Arts District (RAD) Brewing Company

The RAD Brewing Company is different from the other three microbreweries that participated in our project because they had only been open for two months when the data collection took place. They brewed about 52 barrels for the two months that they were open, meaning they have the capacity to package approximately 300 bbl/year. In the two months that they were open, they used approximately 6,655 kWh of electricity and 233 Therms of natural gas per month. The two months of data suggests that The RAD will use approximately 79,860 kWh/year and 2,796 Therms/year. Based on these data, The RAD Brewing uses approximately 266.2 kWh/bbl packaged and 9.3 Therms/bbl packaged.

3.3.1 Energy Savings Opportunities

A couple of opportunities were discovered at The RAD that have the potential to lower their annual energy consumption. *Table 6* reveals the energy efficiency opportunities that were found within The RAD Brewing Company. The two opportunities that were identified within The RAD's facility are common opportunities that were identified within the other three breweries that participated in our project. Although both opportunities have the potential to save around the same amount of utility costs and avoid around the same amount of CO_2 emissions annually, installing a better seal at their refrigerated storage area may have a lower initial investment cost than installing insulation around pipes at their condensate return system.

Opportunity	**Estimated Reduction Impact (%)**	**Electricity Saved (kWh)**	**Natural Gas Saved (Therms)**	**Cost Saved ($)**	**CO_2 Emissions Avoided (lb)**	**SO_2 Emissions Avoided (lb)**	**NOX Emissions Avoided (lb)**
A better seal could be installed at refrigerated storage area door to prevent cool air leaks	5	1,398	0	133	1,213	0.62	0.78

Insulation could be installed around the pipes at the condensate return system next to boiler	10	0	126	119	1,473	0.01	1.24
Total		1,398	126	252	2,686	0.63	2.02

Table 6. *Opportunity summary for The RAD Brewing*

3.3.2 Current Sustainable Practices

Although The RAD just began brewing two months prior to our project's data collection, it's important to note that nearly all of their brewing equipment is Energy Star certified. An initial investment in energy efficient equipment will guarantee reduced energy consumption and cost in the future.

3.4 Cellarest Beer Project

Cellarest Beer Project is the smallest brewery that participated in our project, operating around 30 hours per week, they have the capacity to package around 200 bbl/year. Historical energy consumption data collected from Cellarest included 12 months of electricity and natural gas costs only. As actual energy usage data was not provided, the below analysis uses a unit cost rate from a nearby brewery to estimate the amount of kWh and Therms. It was determined that Cellarest uses around 69,691 kWh of electricity per year and 1,581 Therms of natural gas per year. Considering Cellarest has the capacity to package around 200 bbl/year, each barrel of beer brewed uses approximately 348 kWh/bbl packaged and 7.9 Therms/bbl packaged.

3.4.1 Energy Savings Opportunities

Opportunities discovered within Cellarest have the potential to lower their annual energy consumption. *Table 7* lists the quantifiable opportunities that were identified within Cellarest. The energy savings opportunities that were identified within Cellarest were unique compared to the opportunities identified within the other three breweries that participated in this project. For example, Cellarest's refrigeration system is unconventional in the way that it is cooled to required temperatures via a window air conditioning unit that is wired to run continuously. By permitting an automatic shutoff when the setpoint of the refrigeration storage area is reached, the air conditioning system will not run constantly. This opportunity has a significant energy consumption reduction impact because if the A/C is not running constantly, it will not be consuming electricity constantly. On the outside of Cellarest's brewery, the A/C unit used for refrigeration is exposed to afternoon sun. Shading the outside of the A/C unit will reduce its amount of heat absorption by the sun and reduce the amount of electricity it uses to cool the refrigerator. Both of these opportunities require little to no initial investment costs and could save Cellarest approximately 4,912 kWh of electricity and $467 in utility costs annually. Since Cellarest uses an electric water heater more often than their natural gas water heater, the identified opportunity that has the potential to reduce their natural gas consumption may not be as significant as estimated if implemented.

Opportunity	**Estimated Reduction Impact (%)**	**Electricity Saved (kWh)**	**Natural Gas Saved (Therms)**	**Cost Saved ($)**	**CO_2 Emissions Reduced (lb)**	**SO_2 Emissions Reduced (lb)**	**NOX Emissions Reduced (lb)**
Improve refrigerated storage to permit automatic shutoff when setpoint is reached	15	3,658	0	348	3,173	1.63	2.04
Provide shading for windows and A/C unit to minimize impacts of heat absorption	15	1,254	0	119	1,088	0.56	0.70
Add insulation around ventilation fan	2	167	0	16	145	0.07	0.09
Add insulation around garage doors in front of building	7	585	0	55	507	0.26	0.33
Switch from incandescent to LED string lights in tap room	2	83	0	8	72	0.04	0.05
Add insulation to hot and cold water lines	10	488	71	113	1,253	0.22	0.97
Total		6,235	71	659	6,238	2.77	4.18

Table 7. *Quantified opportunity summary for Cellarest*

Additional energy efficiency opportunities discovered within Cellarest are not as easily quantified, but can still reduce their overall energy consumption. Such opportunities include performing regular maintenance practices on equipment, adjusting equipment to its optimal set point required for operation, ensuring the door to refrigerated storage areas is closed most of the time and insulating small holes around the building that could be leaking warm or cool air.

3.4.2 Current Sustainable Practices

Cellarest uses an Energy Star certified electric water heater that is used more frequently than their gas water heater. This practice reduces the amount of natural gas used to heat their water and supports energy efficiency through the use of Energy Star certified equipment. Cellarest is also one of the first breweries to work with ClimateHound, a company that assists food and beverage businesses in calculating their carbon footprint, implementing reduction strategies and easily achieving their sustainability goals. Cellarest coordinated with ClimateHound to prioritize their environmental responsibility and become carbon neutral.

3.5 Overall Results

Overall results from the review of energy efficiency opportunities at these four breweries are presented below. *Figure 2* compares the size of all four breweries based on the amount of barrels packaged per year. The figure reveals that Wicked Weed and Hi-Wire package a significantly larger amount of barrels annually than Cellarest and The RAD. Due to this difference in size, the overall results will compare Wicked Weed and Hi-Wire as “large sized breweries” and The RAD and Cellarest as “small sized breweries” The separation of the four breweries into two categories allows a more in-depth comparison that could not be achieved if all four were compared on the same scale. Although Wicked Weed and Hi-Wire are both considered Large Breweries, it is important to note that Wicked Weed is significantly larger than Hi-Wire.

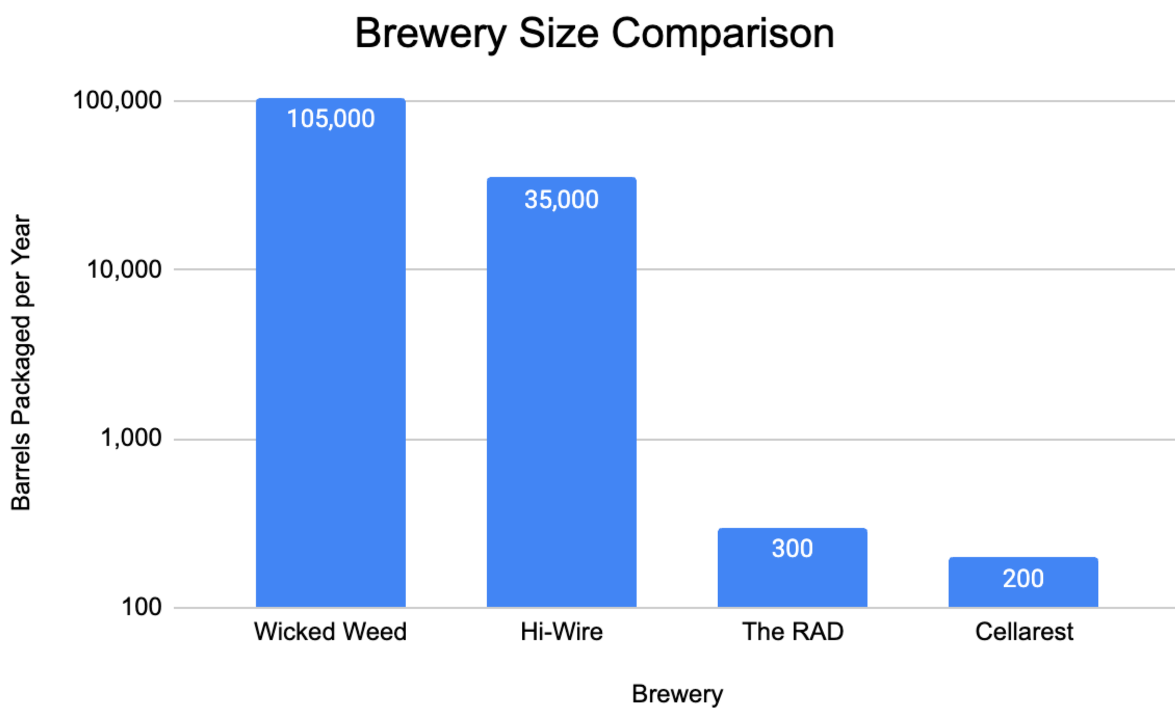

Figure 2. *Size comparison of all four breweries based on annual packaging capacity (bbl/year)*

Figures 3 and 4 compare current electricity usage (blue) and potential electricity usage if all of the identified energy efficiency opportunities were implemented (red) within the large and small breweries. The figures are measured by kWh per barrel packaged. These data reveal that at the small sized breweries, The RAD has the potential to save approximately 4.7 kWh/bbl packaged and Cellarest has the potential to save approximately 30.7 kWh/bbl packaged. As for the large sized breweries, Hi-Wire has the potential to save approximately 0.6 kWh/bbl packaged and Wicked Weed has the potential to save approximately 0.4 kWh/bbl packaged. This difference in potential savings between the small and large sized breweries is due to more energy savings opportunities identified within the refrigeration areas of the small sized breweries, which is the main consumer of a brewery's electricity. Especially at Cellarest, where the largest energy reduction potential found in the identified opportunities were within their refrigeration system.

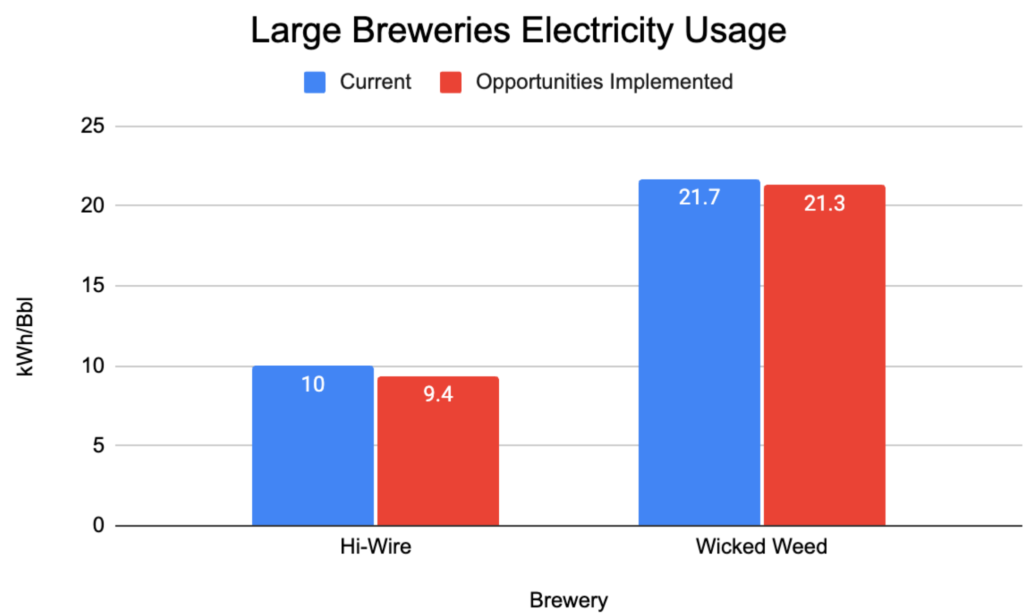

Figure 3. *Comparison of current electricity usage and potential electricity usage after implementing identified opportunities in large breweries*

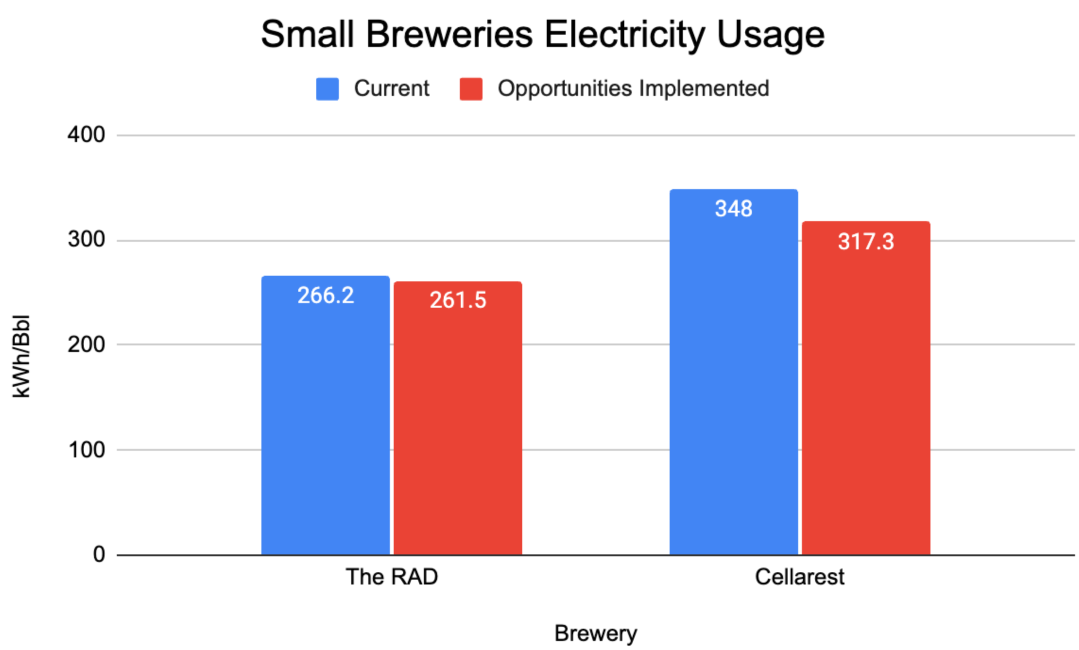

Figure 4. *Comparison of current electricity usage and potential electricity usage after implementing identified opportunities in small breweries*

Figures 5 and 6 reveal the difference between current natural gas consumption and natural gas consumption if energy efficiency opportunities were implemented in each brewery. The figures are measured by Therms per barrel packaged. The figures show that at the large sized breweries, Hi-Wire has the potential to save approximately 0.5 Therms of natural gas per barrel packaged and Wicked Weed has the potential to save approximately 0.07 Therms of natural gas per barrel packaged. At the small sized breweries, The RAD has the potential to save around 0.42 Therms of natural gas per barrel packaged and Cellarest has the potential to save around 0.4 Therms of natural gas per barrel packaged. The data reveals that Hi-Wire has the greatest potential to lower their natural gas usage. This is due to the significant amount of energy-savings opportunities that were identified within their hot water and steam systems. The energy efficiency efforts that were already in place at Wicked Weed before this project took place may explain why they do not have as much potential to lower their electricity or natural gas usage per barrel packaged as the other breweries. This project uses data provided by the Brewers Alliance Energy Efficiency Manual (Brewers Association, 2010) to determine the amount of natural gas that is used per barrel packaged, which may not consider natural gas usage for breweries as small as The RAD and Cellarest. Considering Cellarest uses electricity to heat their water more often than natural gas, the amount of natural gas they could save per bbl packaged may be lower than this data suggests.

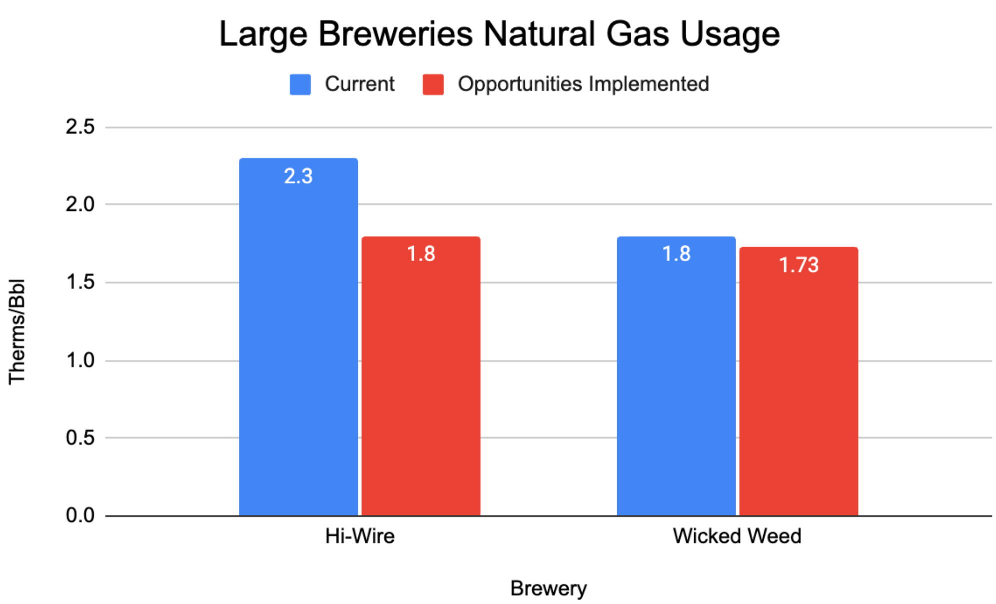

Figure 5. *Comparison of current natural gas usage and potential natural gas usage after implementing identified opportunities in large breweries*

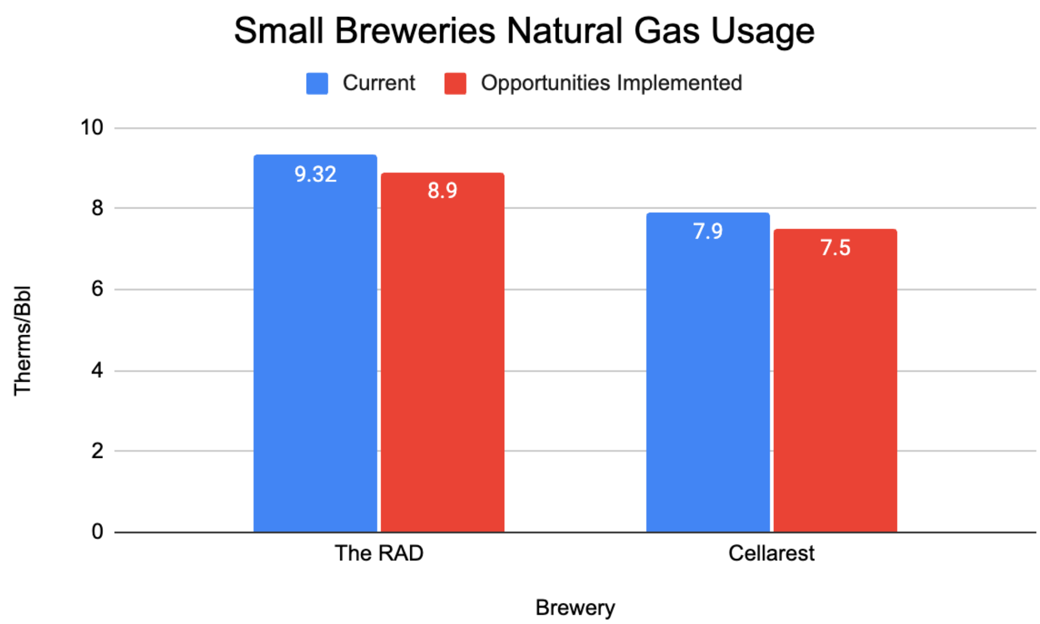

Figure 6. *Comparison of current natural gas usage and potential natural gas usage after implementing identified opportunities in small breweries*

Figures 7 and 8 represent how much cost large and small sized breweries would save in each area within a brewery if they implemented each opportunity that was identified. The figures categorize different areas of the brewery as brewhouse, refrigeration, compressed air, lighting, and “other” which represents miscellaneous opportunities that were identified. An example of opportunities identified in the “other” category was optimizing the usage of industrial sized fans at Wicked Weed or providing shading for the outside of an air conditioning unit at Cellarest to reduce heat absorption. The figures reveal that Hi-Wire has the potential to save $17,181 in their brewhouse area alone, which is greater than all of the cost savings from each opportunity identified within the other three breweries combined.

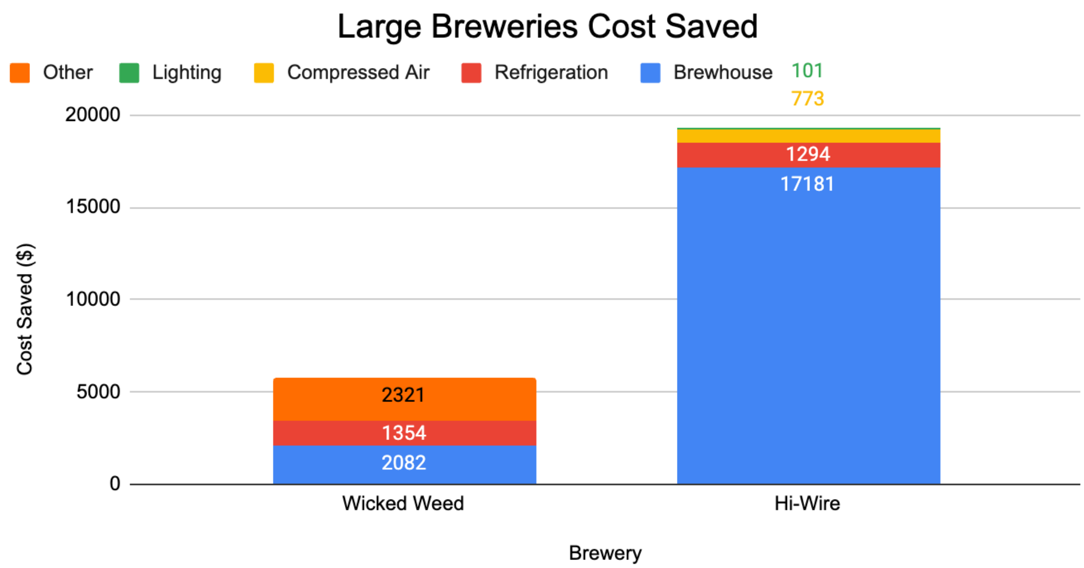

Figure 7. *Visualization of utility costs saved per year if opportunities were implemented in large sized breweries*

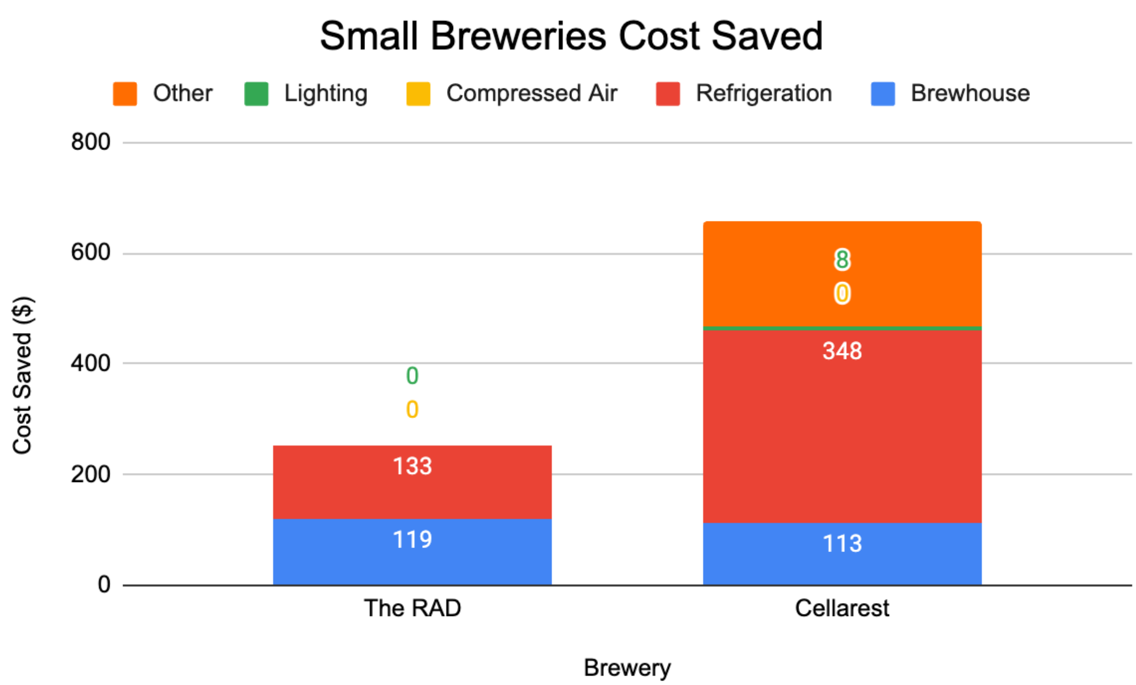

Figure 8. *Visualization of utility costs saved per year if opportunities were implemented in small sized breweries*

4. Conclusion

4.1 Research Implications

Discovering energy efficiency opportunities within Asheville's craft brewing industry allowed the determination of potential environmental and economic impacts of energy efficiency improvements made within a brewery. This project worked with four breweries in the Asheville area to identify energy-savings opportunities within their facilities. There were energy savings opportunities that were identified in each brewery that participated in this project. The majority of energy efficiency opportunities identified were in the hot water and steam systems and refrigeration areas of a brewery. Another major opportunity that was identified is maintaining regular maintenance schedules on equipment. Regular preventative maintenance will ensure equipment is meeting its energy-efficiency potential while extending the amount of time the equipment can operate successfully.

The Energy Star Treasure Hunt that was used for this project sets a goal for breweries to reduce their energy consumption by 10% within the year. If each brewery implemented every opportunity that was identified through this project, Hi-Wire would reduce their annual natural gas usage by 10%, and Cellarest would reduce their annual electricity usage by 10%. Each year, 20,990 Therms of natural gas and 73,360 kWh of electricity would be saved, 309,336 lb of CO_2 emissions would be avoided, $25,827 would be saved in utility costs at all four breweries combined. It is important to note that the percentage of electricity or natural gas that is used by each category of a brewery is taken from the Brewers Alliance Energy Efficiency Manual (Brewers Association, 2010), which might not account for breweries as small as Cellarest and The RAD. This might indicate that other benchmark data should be used to reflect energy use at these facilities.

4.2 Future Research

The best approach for these facilities is to look at current energy use and to continuously identify opportunities to save energy as a part of a constant improvement mindset. An extension of this study would be to analyze a return on investment for the implementation of each energy efficiency opportunity that was discovered within each facility. The Energy Star Treasure Hunt is a useful tool that was designed specifically for microbreweries to discover energy savings opportunities within their facility. The utilization of this tool during our project proved extremely beneficial in identifying such opportunities, and it is highly recommended to other breweries that want to prioritize energy efficiency within their facility in the future.

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