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# A Case Study in Small Brewery Sustainability

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## ABSTRACT

This report presents the growing need for feasible environmental sustainability measures geared toward small brewing operations while reducing a business's overall environmental impact, specifically highlighting the efforts of Gilded Goat Brewing Company in Fort Collins, CO. These efforts focused on measuring, monitoring, benchmarking, and goal setting for the various ingredients, utilities, and waste products throughout the brewing process. Based on data from the Brewers Association, our analysis determined that, compared with other breweries in the size category (microbrewery), Gilded Goat uses less water than the average microbrewery, has similar usage to the average in electricity

and fuel, and uses more CO<sub>2</sub> than the average. From these findings, several recommendations have been identified for Gilded Goat Brewing based on ingredients, employee engagement, community involvement, and energy efficiency. Most of the recommendations included in this report are opportunities geared toward efficiency throughout the brewing process and identifying key areas for improvement through employee engagement. These suggestions are focused on short- and long-term implementations that can reduce the overall environmental impact of Gilded Goat Brewing Company and similar small brewing operations.

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## Introduction

The craft beer segment has continued to grow, now accounting for 12.9% of the overall beer market (1), despite an increasing incidence of water shortages and environmental impacts to water quality in parts of the United States (2). While only 3% of breweries have reported their energy/utility benchmarking data to the Brewers Association (BA), the annual brewery sustainability report is the most accurate industry benchmark measuring trends in sustainability with regard to production size and region. The BA classifies small breweries producing under 15,000 bbl of beer annually as microbreweries. This segment of the industry saw a 15% increase between 2017 and 2018, now representing 4,522 operating microbreweries across the country (1). Many breweries already consider the environmental impacts of their operation an important aspect of the craft beer industry and are working toward becoming more economically, environmentally, and socially responsible. However, the large, regional breweries are typically able to implement interventions with a higher cost-to-benefit ratio and earlier return on investment than is typically realized by smaller breweries. Without the economic impact expected, smaller breweries are not motivated, and thus a knowledge gap exists with regard to best practices. While it is easier to see more value in sustainability projects with a high impact, new and small craft breweries should focus on benchmarking and prioritization of project work that does meet financial goals within the resources available for the purpose of improving sustainability. Understanding how to be more sustainable and reduce resource usage is critical to the future of the brewing industry (3).

Industry requirements and the strong preference consumers show in preferring and choosing manufacturers who prove to be environmentally responsible mean that this is absolutely required

for market success. This shift toward a more sustainable sector not only requires leadership from the industry and specific stakeholders but also needs to be incorporated into the business goals and cultural dynamic of the entire craft beer sector. This paper will explore the current usage and practices for Gilded Goat Brewing Company (GGBC), identify key performance indicators (KPIs), and discuss the various implementations and recommendations discovered throughout the project. The report is meant to provide an introduction and outline for other microbreweries in the beginning phases of benchmarking and moving toward more sustainable operations.

## Key Ingredients

Increased unpredictability both in climate and energy markets has renewed interest in shortening the supply chain for many industries (4). However, American Craft beer has been broadening its supply chain with exotic hops from New Zealand and Australia and a variety of specialty malts from Europe (4). While these specialty products allow variation and creativity in the craft beer sector, which is important for growth and relevance, sustainability advocates should be looking for more locally sourced ingredients that can still create distinguishing flavors. Utilizing local ingredients not only reinforces the current market but also promotes the opportunity for growth in connected sectors. However, this also creates its own challenge in finding the type of hops or the type of malt desired for a recipe, if they are not regularly available in the local market. Understanding the ingredients used in the brewing process, when they are added, and the associated byproducts is important for finding key areas of focus for sustainable initiatives (Fig. 1). This section will dive deeper into the various ingredients used in brewing, the industry averages of utility consumption, and how GGBC compares with these industry averages (Fig. 2).

## Water

Given the concerns of increasing water consumption and declining resource availability, breweries need to be aware of their environmental impact. Therefore, integrating sustainable pro-

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duction and practices into individual operations is becoming increasingly relevant. Nationwide, the average craft brewery uses 7 bbl of water to produce 1 bbl of beer. However, between 2014 and 2018, microbreweries producing less than 1,000 bbl of beer annually have an average use ratio of 19.6 bbl of water per barrel of beer (5). Regional breweries that have an annual production between 15,000 and 6,000,000 bbl have reduced their water to beer ratio to as low as 3 bbl of water to 1 bbl of beer (5). Water quality and availability are a growing concern in many regions, and breweries are making concerted efforts to reduce

their water use ratio. In just 2 years, from 2014 to 2016, microbreweries that responded to the BA annual sustainability benchmarking survey reduced their average water use ratio by more than half (Fig. 3). However, this ratio is determined within the brewery and does not account for water use along the supply chain.

**Malt**

Malt is the most resource-intensive ingredient involved in the brewing process, from farming, malting, and mashing. While

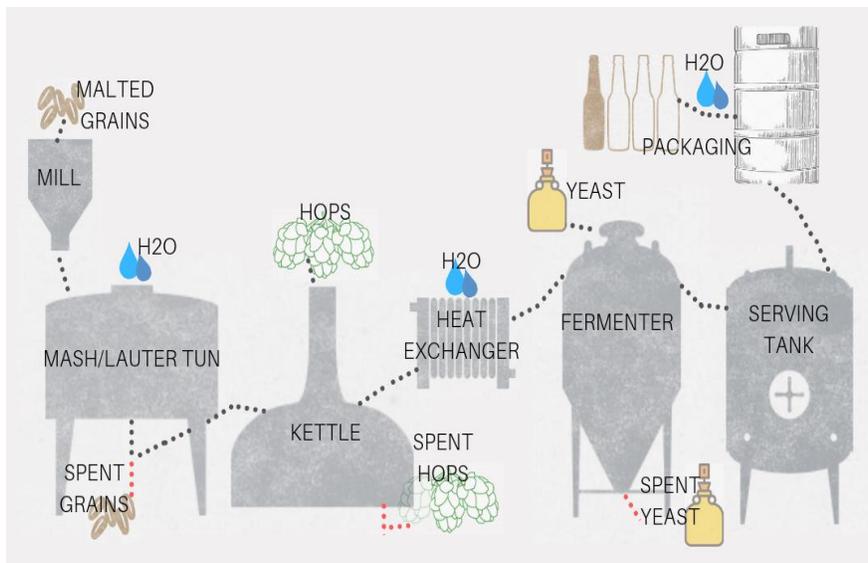


Figure 1. Gilded Goat Brewing Company brewing process.

	Scenario	kWh/bbl	Proj 2021 Cost	Cost Avoidance
Electricity	Baseline	220	\$ 12,834	Baseline
	Top 75%	298	\$ 17,378	\$ (4,543)
	Median	182	\$ 10,613	\$ 2,221
	Top 25%	122	\$ 7,114	\$ 5,720
	Best in class	77	\$ 4,490	\$ 8,344
	Scenario	therm/bbl	Proj 2021 Cost	Cost Avoidance
Fuel	Baseline	3.1	\$ 1,361	Baseline
	Top 75%	17.0	\$ 7,391	\$ (6,031)
	Median	7.4	\$ 3,217	\$ (1,857)
	Top 25%	3.7	\$ 1,609	\$ (248)
	Best in class	2.3	\$ 1,000	\$ 361
	Scenario	lb/bbl	Proj 2021 Cost	Cost Avoidance
CO <sub>2</sub>	Baseline	7.6	\$ 1,137	Baseline
	Top 75%	7.7	\$ 1,155	\$ (18)
	Median	5.6	\$ 840	\$ 297
	Top 25%	5.5	\$ 825	\$ 312
	Best in class	5.4	\$ 810	\$ 327
	Scenario	lb/bbl	Proj 2021 Cost	Cost Avoidance
Solid Waste	Baseline	0.0	\$ -	Baseline
	Top 75%	36.0	\$ 900	\$ (900)
	Median	18.0	\$ 450	\$ (450)
	Top 25%	8.0	\$ 200	\$ (200)
	Best in class	6.0	\$ 150	\$ (150)

Figure 2. Potential cost avoidance calculations at projected 2021 production (Brewers Association Benchmarking Tools 2019; reproduced by permission).

barley farming uses less water than other cereal crops such as oats and corn, production of this raw material requires a significant amount of water and energy before it is even milled into the mash tun at the brewery, all of which is out of the brewer's control. In fact, if water use involved in barley farming was incorporated into the water use ratio for the brewery (volume of water required to produce 1 volume of beer), the true ratio would be in the range of 11–40 gallons of water required per gallon of beer (6). Breweries around the United States import malts from around the world, which contributes an increased carbon footprint compared with locally grown and malted grains, due to long-distance transportation. For example, if the utility use of the farming and malting operations are equal, Belgian malts must then travel 5,600 miles to Colorado compared with the 10 miles traveled by locally grown and malted products. In order to be sustainable as an industry, brewers need to consider the sustainability of their ingredients, not only in distance traveled but also overall practices of these companies from water usage to sustainable farming practices.

Spent malted grain is one of the largest byproducts of the brewing process and often the simplest and least expensive first step in reducing waste (7). Most breweries use local farmers to collect the spent grains, with some proportion becoming compost or silage. These farmers help local breweries be more efficient in their waste stream and also save money on feed for their cattle by providing valuable protein (25–30%) from the spent grain to the diet of the livestock (8). However, not all livestock animals are capable of consuming this byproduct. Every effort must be made to keep this valuable food source out of the landfill.

### Hops

According to the U.S. Department of Agriculture, 73% of our nation's hops are grown in the state of Washington, with the remainder split between Idaho and Oregon. After the Pacific Northwest's hop production reached a record 104 million pounds in 2017, the Hop Growers of America, a Yakima-based nonprofit trade association, warned hop farmers that the industry has reached a saturation point (9). Since 2012, hop production in the United States has increased by nearly 77%, and the rising demand and lower yields have driven the price of hops up by more than 250% over the last decade (9). This increased demand is leading more brewers to search out locally grown hops. However, due to specific environmental conditions required by many hop varieties, locally sourced versions of the same varieties are not often feasible for many breweries seeking to maintain particular hop characteristics in their beer.

Hops can be difficult to repurpose after the brewing process, particularly for small breweries with very small amounts of

spent hops. The main method of sustainable disposal for hops is reuse as fertilizer or compost. As a very nitrogen-rich byproduct of beer, hop material can be a healthy addition to garden soil and is similar to composting other green material. The residual bitterness of spent hops makes it difficult for them to be used as an animal feed. Some cattle will eat the hops but typically only if they are low bitterness or are topped with the hot spent grain that helps to cook the leaves. Even then, many farmers are concerned about the health impact to their livestock by feeding them spent hops. Most hop material is delivered to brewers as hop powder pellets, which only adds a degree of difficulty as most of the material ends up in the trub, which is nearly impossible to separate and dispose of. As an industry, reducing hop waste would require a dramatic shift in material preference toward extracts, but it would also then require the hop extract plants to dispose of the waste sustainably.

### Yeast

While brewers depend on yeast to produce beer, yeast is eventually a byproduct of the brewing process. As a part of the trub and wastewater, spent yeast increases the overall biochemical oxygen demand (BOD) and total suspended solids (TSS), often exceeding the amount permitted in typical wastewater discharge levels before dilution. With few sustainable opportunities available for yeast disposal, most breweries collect and dispose of it by sewerage. Some farmers will allow mixing into spent grain depending on their livestock mix, but most animals will not eat it because of the bitterness from the hop acids mixed with the yeast in the trub. Wastewater treatment facilities can potentially utilize this yeast as an aid for breaking down organic materials in the wastewater stream during nitrate removal processes (i.e., denitrification) if introduced during particular process points. While this is a newer application of yeast, it is definitely worth exploring at the local community level. (Editor's note: While typically not feasible in our experience, this application is viable and may be applicable in some situations and localities.)

Hops and yeast are considered high-strength wastewater. These high-strength effluent streams are typically high in BOD and TSS. Breweries in most municipalities are required to treat, neutralize, and/or dilute their wastewater before discharge, depending on city regulations and local wastewater treatment facilities. It is likely that these requirements could become more stringent for brewery-saturated areas or as populations grow.

## Materials and Methods

This project has been focused on collecting and analyzing brewery data to provide GGBC with an outline for an environmental management program that will include KPIs, bench-

	2014	2015	2016
<b>Water Use Ratio (bbl/bbl packaged)</b>			
0-1,000 bbls/yr	37.33	43.95	17.97
1,000-10,000 bbls/yr	10.46	11.37	8.78
10,000-100,000 bbls/yr	6.21	5.58	5.86
100,000+ bbls/yr	4.52	4.96	4.89

**Figure 3.** Craft brewery water usage ratio based on production size (Brewers Association Benchmarking Report 2018; reproduced by permission). Note: The Brewers Association has determined that many small (0–1,000 bbl/year) and even some mid-sized breweries (1,000–10,000 bbl/year) do not have dedicated water meters for brewing operations, and this can lead to inflated water usage numbers for these breweries.

marking tools, and overall goals for reduction. Gilded Goat's data were collected and analyzed to set initial baselines and determine feasible goals based on industry averages comparative to Gilded Goat's production size. This was accomplished using the BA benchmarking tools, which show brewery averages in various utilities based on production size and region.

As with any business, collecting data and benchmarking this data over time will provide the greatest insight to overall usage and cost and will facilitate realistic long-term goal setting. While there are a variety of tools available for benchmarking, craft breweries typically do not have the time or resources to manually collect and enter large data sets. The BA benchmarking tool aids to simplify this process by utilizing limited input data to calculate the cost and potential savings for various reductions, while providing the environmental benefits of reaching goals equivalent to vehicles removed from the road. The BA benchmarking tool also calculates the cost and potential savings for various reductions and allows you to set reduction goals. The majority of data entered into the benchmarking tools were provided by GGBC's utility bills, including electricity, gas usage, and purchased carbon dioxide. A combination of monitoring of submeters and physical measurements was used to determine water usage.

### BA Benchmarking Tools

The BA benchmarking tools provide an opportunity for breweries of all operating sizes to enter and organize a variety of KPIs of usage and cost data. The program can generate various graphs and visuals based on KPIs and compare specific brewery data to average industry usage based on regional locations or production size. These can be beneficial tools not only when working toward reduction but also for setting feasible goals and creating a standard for KPIs and sustainable leadership in the industry.

These tools are relatively new and are only used by roughly 3% of breweries nationwide, which likely skews the data when only seven breweries of the smallest production size (0–1,000 bbl/year) entered their 2017 data. Not only does this make it difficult to benchmark, but it also likely represents the few breweries of this size that are interested in sustainability or have limited resources to provide the required input data—potentially introducing bias.

In order to have more complete data and better benchmarking analysis across the industry, more breweries need to participate in this process. Through their sustainability sub-committee, composed of brewery representatives from across the nation, the BA determined that the original benchmarking tools were difficult to use for a variety of reasons. This led the BA's Sustainability Mentor, John Stier, to help the project team develop a further simplified scenario planning tool to analyze the data. This new tool allows for inputting goals and projected future costs for various KPIs, as well as benchmarking across the industry, and allows demonstrating potential cost savings through a more approachable user interface. Currently, these tools have been updated as a downloadable tool that can be more convenient, efficient, and productive for individual breweries and the entire industry. Using these tools has been a crucial step in establishing a long-term sustainability plan for GGBC, but inputting and using data is a long-term task that needs to be added to maintenance schedules.

The tool shows the average, top 25%, and best in class for the different KPIs, which allows breweries to set attainable goals for efficiency before working toward extensive and expensive projects. The benchmarking tool also allows for standardization

across the industry, which provides a more collaborative effort in sustainability implementations. This is important for long-term industry standards and goals, as well as data management for long-term industry resilience.

### KPIs and Interventions

GGBC, while a small and relatively new microbrewery, has already adopted many of the tools that lead to sustainable business practices and promote long-term resilience. With the primary goal of reducing utility use, standard operating procedures (SOPs) have been implemented for each step in the brewing and sanitation processes, including proper calibration of flow meters and pumps. These standards create the proper environment for integrating KPIs, which should then lead to the creation of a management plan or environmental management system to monitor sustainability initiatives, goals, and benchmarks across industry averages.

For utility-based interventions, we focused on benchmarking through both the BA tools and Fort Collins's ClimateWise program (numerous municipalities across the nation have similar programs). The latter program assists in tracking energy efficiencies, setting goals, and providing recognition for reaching goals and incorporating new aspects of sustainability into the business, such as employee education or social media content. The utility-based interventions also focus on measuring and monitoring, which can lead to better leak detection and overall efficiencies. Ingredient-based interventions typically focus on the supply chain of these ingredients and byproducts. For each key ingredient—water, hops, malt, and yeast—this section will detail more specific interventions and recommendations that identify reduction opportunities based on the compounded savings to support the triple bottom line of economic, social, and environmental sustainability.

### Water

The first step to reducing resource consumption is to measure and monitor usage to determine where reductions are possible and the feasibility of various implementations. A typical brewery uses water in three main areas: the brewhouse, cellar and packaging, and taproom functions. GGBC is a taproom-focused microbrewery that uses a 7-bbl system custom designed for their small space, which helps create a more efficient product flow around the brewhouse and into the cellar. This also reduces the length of hose needed for transferring, further reducing needed water in prerinsing, cleaning, sanitation, and pasteurization. As a taproom-focused brewery, packaging operations are very small, thereby reducing the largest category of water use. Pouring directly from serving tanks and kegs to the taps reduces Gilded Goat's water consumption compared with running packaging lines. Utilizing four 8-bbl serving tanks allows for fewer kegs to be used and cleaned per batch.

Within the brewing process, there are many different implementations that could reduce water usage, thereby also reducing wastewater discharge: for example, during the mashing and lautering process, use of dry methods to remove the grains from the mash tun, via a brush, rake, or pump. At Gilded Goat, reducing spray time during mash tun cleaning and kettle cleaning as well as recapturing heat exchanger water saved approximately 15,000 gallons/year. Recapturing cooling water via heat exchanger output is another example of water conservation employed by most breweries.

Investing in advanced clean-in-place (CIP) and sanitize-in-place (SIP) methods and optimized CIP procedures can have

major water and effluent savings. An optimized SOP for fermenter and serving tank CIP/SIP processes can reduce water use dramatically. Using a minimum amount of water and chemical to provide adequate tank cleaning and sanitation, together with a pump equipped with a variable-frequency drive running at the appropriate pressure to activate the spray ball, will reduce water use for each cleaning cycle of a tank. Standalone or skid-based CIP carts provide incremental savings. These CIP systems can have single or multiple tanks depending on the brewery's water, energy, and chemical usage. The single-tank systems are the most common for simple cleaning, when only a wash and/or rinse is needed, where chemicals from each cycle are neutralized and dumped to the drain after a single pass. Multi-tank CIP skids can save and reuse cleaning and sanitation chemicals, which saves energy and reduces water and chemical usage. In many instances, cleaning chemicals can be reused for multiple cleaning cycles by monitoring the pH, turbidity, and effective concentration of the solution after each cycle. At Gilded Goat, CIP and SIP procedures were updated to reduce total water per cycle from 15 to 10 gallons, in addition to reducing post-CIP/SIP water rinse time from 5 to 2 min. This updated SOP saved approximately 500 gallons per year. Many of these improvements have been fine tuned to Gilded Goat's processes, but through measurement, reductions are possible.

Once benchmarks and goals have been set, introducing submeters at various process points is the most optimal way to monitor efficiency in the brewhouse by associating usage data with each individual step in the brewing process. Even with general baselines for the process, brewers can see if they used more water than anticipated, which will alert them to do maintenance checks and identify any leaks that could contribute to excess water use. Regular maintenance checks and carrying out a water use survey are useful steps toward identifying opportunities to reduce water. At a minimum, record how long it takes to fill a 5 gallon bucket with the washdown hose. Then, using a timer, record the duration of washdown hose use during particular activities, especially during a brewday. Even this most basic form of monitoring will increase awareness of water use, leading toward reduction.

Initially, GGBC was unable to track total water use as easily as single-building breweries do due to the structure of their joint water system with neighboring businesses, a common feature of many multi-use and multi-tenant developments. Using a newly installed submeter on the brewery's main water supply, in addition to physical calculations (such as washdown hose flow rate and spray time, sight glasses, and flowmeters), we were able to calculate a total water use ratio of 4.5 bbl of water for 1 bbl of beer, down from nearly 8 bbl of water per barrel of beer during the first 2 years of operation. Additionally, improving brewhouse efficiency by increasing per batch yield via more efficient transfers and loss avoidance would also reduce water use per barrel of beer.

While various measures can be taken to create a more circular system for water in the brewhouse, such as reusing rinse water, the potential costs for these investments are high, and other efficiency measures should be taken first. These simple interventions can save the brewery hundreds of gallons of water per year, but they often require more time and effort from the brewery staff. A company ethos focused on sustainability will help to drive these efforts among the staff.

### Hops, Grain, and Yeast

GGBC typically gets malts from several sources—Rahr, Troubadour Maltings, Root Shoot Maltings, and Weyeremann, among

others. Troubadour Maltings and Root Shoot Maltings are local malting companies in Northern Colorado that source local barley for the production of malt. The intensive process of transporting and malting grain is critical in evaluating the environmental footprint of beer, especially considering the impact that the changing climate may have on barley production over the coming decades (10).

Two of the challenges for reducing environmental impacts with hops and grain are the cost and transportation methods. These can be difficult to address when few ingredients can be only locally sourced. However, finding more opportunities to purchase locally can be the best opportunity for sustainability, even if this can only be done seasonally. To start, a brewery should consider the environmental footprint of ingredients as well as the actual difference in cost of goods sold before determining how much of the particular raw material can be sourced locally.

Packaging is one of the major sources of waste associated with the hops, grain, and yeast. Pallets, plastic wrap, grain bags, and taproom waste represent a significant amount of often non-recyclable waste. GGBC often reuses grain bags for other waste, since the majority of these bags are not recyclable (confirm with your local recycler), and GGBC has been working with a variety of local organizations and the maltsters to come up with a recyclable bag or a way to reuse or recycle them.

Another source of waste with these ingredients is the by-products they produce. Spent hops, yeast, and grains all need to be disposed of after the brewing process, and there are limited options for reuse. Spent grain is provided to local farmers for cattle feed, but the yeast and hops are difficult to reuse. Yeast has some opportunity for reuse through multiple repitches, which reduces waste and spreads the cost of the culture across many brews. While yeast and hops are both nitrogen rich and great for compost, there are many rules and regulations for composting, which vary state by state. For example, in Colorado, businesses cannot donate compost material to organizations or gardens and either have to pay for it to be collected and composted via private entities or have an on-site composter. Understanding local laws in your area is important for finding solutions, which could also vary by the amount of byproduct. Local waste officials will be the greatest source of knowledge in terms of regulations and potential solutions.

### Energy Efficiency

Measuring and benchmarking current utility data should be the first step in improving efficiencies within operations, which will also bring additional cost savings. Measured through electric and fuel bills, energy is a major utility cost for GGBC, with electricity costs being more significant than fuel and with most of the electrical energy going toward refrigeration. This breakdown is consistent with other breweries of this size category, according to the BA (5) (Fig. 2). Energy utilization should be the primary focus of conservation for the brewery, because it can lead to cost savings and reduced emissions.

Data from the U.S. Environmental Protection Agency show that refrigeration, packaging, and compressed air consume 70% of the U.S. breweries' electricity and that the average brewhouse accounts for most natural gas and coal use at 45% (11). However, this varies by breweries depending on equipment, location, and overall type of production. Certain costs and resources, such as lighting, heating, and cooling are necessary to operate any brewery regardless of production size. For breweries with production less than 10,000 bbl of beer annually, these baseload operating costs represent a significant portion of the

brewery’s overall utility expenses (5). As production increases, these baseload costs become a smaller portion of total expenses, and the variable costs will fluctuate with production. Lowering utility usage per barrel of production essentially mitigates against increasing energy prices. These data suggest that optimizing cold storage, such as walk-in coolers and freezers, merchandising coolers, glycol chillers, and the building’s HVAC can have a large impact on the overall energy consumption of the brewery. Specifically, upgrading rooftop cooling units to use cold air and deploying vinyl door flaps on cooler doors are inexpensive, high-impact interventions.

To better monitor and understand GGBC’s operational efficiency, the project team worked with Precision Fermentation to use their Brew Monitor device that provides real-time monitoring during the fermentation process. This allowed us to see pH, gravity, dissolved oxygen, pressure, conductivity, and internal/external temperatures in real time. This system of monitoring reduced beer waste from manual measurements. All of these measurements help with the accuracy and consistency of each batch and improve overall operational efficiency. These measurements can also show when specific thresholds are reached, which can reduce tank occupancy time and provide energy and cost savings.

**Electricity**

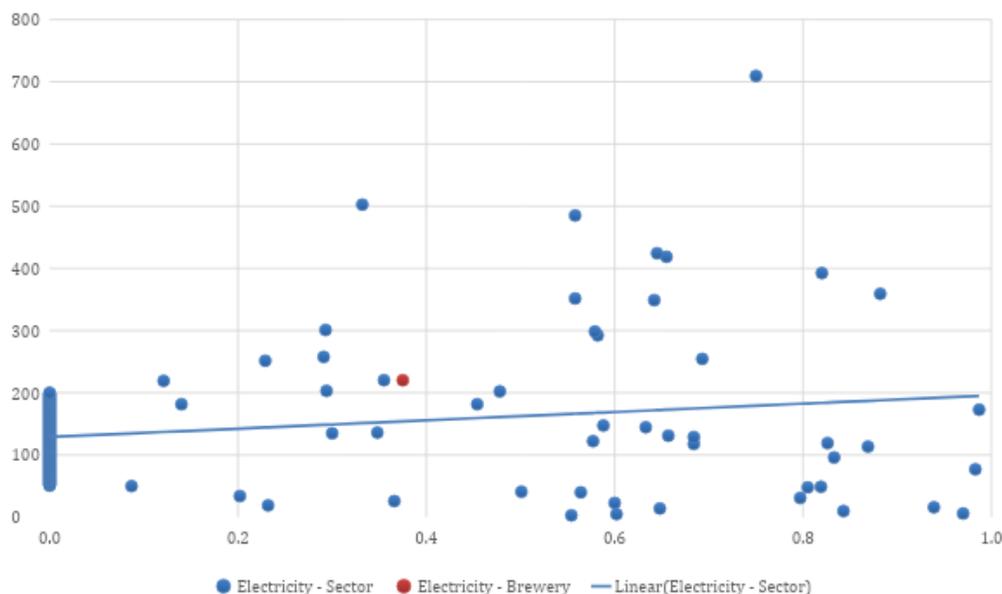
Based on the BA’s 2017 Benchmarking Report, energy has remained the leading cost for overall breweries, with electricity constituting the majority of that cost. Energy typically represents about 70% of all utility costs, regardless of brewery size, and energy efficiency should therefore be a priority focus (5). While many breweries use more fuel than electricity, electricity costs across the nation have continued to rise. Increasing energy efficiency reduces operating costs and has associated environmental benefits in terms of emission reductions. According to the BA’s data, the average craft brewery with production under 1,000 bbl/year uses 182 kWh for every barrel of beer (5). GGBC currently uses an average of 220 kWh/bbl, slightly above the microbrewery median level. Therefore, the 2021 electricity

usage goal for Gilded Goat is 182 kWh/bbl average for this production size, which would save \$2,221 annually (Fig. 2). Across the industry with production under 1,000 bbl/year, for breweries that report data to the BA, there is a wide range of usage from 77 to 709 kWh/bbl (Fig. 4). This reiterates the necessity for standardization and industry-wide collaboration on benchmarking and sustainability initiatives.

GGBC worked on efficiency projects before opening, focusing on simple, cost-effective solutions that could reduce their environmental impact and also provide small cost reductions. The facility’s interior lighting consists of all LED fixtures controlled by labeled dimmer switches, and exterior lighting is also LED and controlled by switches or photocells. Electricity is used for upfront coolers, the dishwasher, and other small kitchen electronics utilized by the front-of-house. It also powers the commercial-grade refrigerator and freezer, the 60-gallon air compressor, and the majority of the brewing equipment. Automated equipment, variable speed drives for pumps and motors, and an efficient hot water heater allow for more energy reductions and can therefore reduce overall costs.

One challenge for benchmarking electricity usage at GGBC, and likely many other breweries, is the overall building layout. The brewery consists of the taproom, the office, three bathrooms, and the brewhouse. For measuring and monitoring purposes, we have determined that 90% of energy usage is in the brewhouse and 10% is in the front of house and office. This definition allows GGBC to better determine consumption and identify opportunities for improvement and efficiency gains in the long term.

The next step in energy efficiency is to incorporate an energy plan, set goals, and work with all employees to reduce unnecessary usage. This includes front-of-house closing checklists to include “turning off lights” and making sure all equipment is being turned off when not in use. In small operations, employee engagement is the primary driver of small electrical savings. Comparing peak usage times to production time and peak business hours to determine where energy usage is high can help determine areas of focus. Another best practice is having a



**Figure 4.** Gilded Goat Brewing Company’s electricity usage (kWh/bbl) across the industry based on production size (Brewers Association Benchmarking Tools 2019; reproduced by permission).

maintenance schedule for daily operational equipment, which will result in lower operating costs and lower usage (11).

### Fuel

Typical brewing systems use a higher percentage of natural gas for their energy than electricity. Managing this energy usage against KPIs is the best first step, after benchmarking, to improve energy reduction efforts. GGBC has a much lower fuel usage than average breweries due to less fuel-powered equipment within the brewhouse, which typically has the largest energy consumption of breweries, such as powering a steam boiler. The average craft brewery with a similar production size to GGBC uses 7.4 therms/bbl according to the BA (3). GGBC is currently only using an average of 3.1 therms/bbl, which is considered in the top 25% of breweries producing under 1,000 bbl annually (Fig. 2).

GGBC only uses natural gas to heat the kettle and the hot water heater. The kettle is the most energy-intensive step in the brewing process, because most beers require a 60–90 min boil time. Steam boilers have been proven to be highly efficient and cost effective in generating energy for many processes and heating applications. Maintenance, efficiency tests, and determining KPIs are the best steps to consistent and efficient boiler production. Currently, Gilded Goat has a 0.4 MMBtu/h kettle that is exempt from air pollution emissions reporting (12). Domestic hot water for the brewery is provided by one 91-gallon natural gas water heater with an efficiency rating of 80% (12). With efficient equipment and a low annual production, the brewery is able to keep their fuel usage low, but even with growth in production, other breweries have proven that it is possible to keep usage low (Fig. 5).

With the high energy usage, between electricity and natural gas, GGBC will need to focus on small efficiencies until it can reach the top 25% for their production size across the BA's benchmarking data (Fig. 2). At that point, it becomes more feasible to do an energy assessment and look into the potential for renewable energy. While the project team has already had an assessment done to determine the costs, benefits, and payback period for solar, this is a project far down the road. A small local

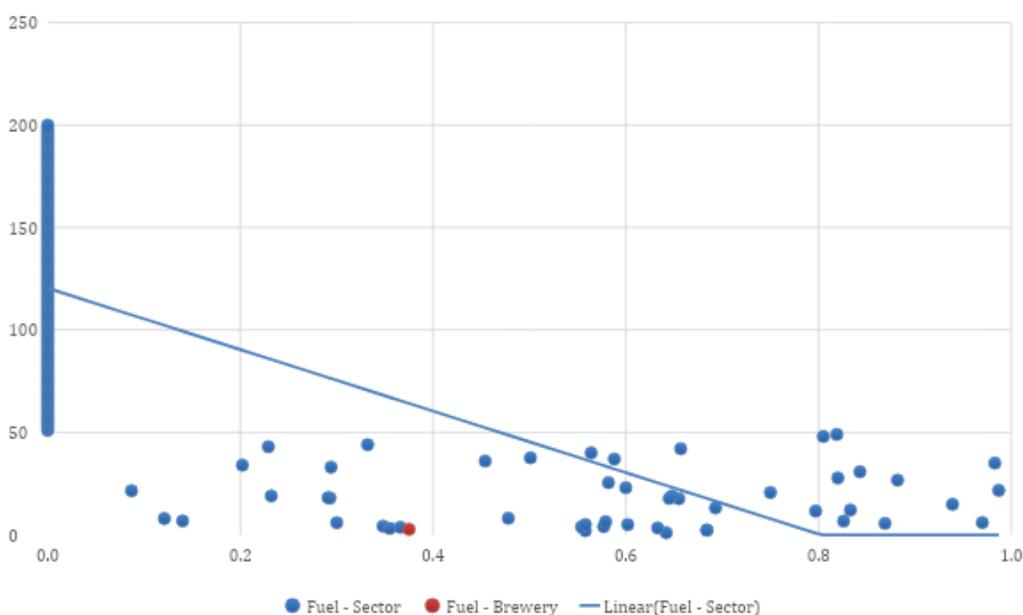
solar company also provided a report of various solar panel options that Gilded Goat could participate in, including local solar programs through the city. Staying connected with local government rebates and opportunities is important for any small business and can often provide long-term benefits not only in usage and cost reductions but also in community involvement and networking.

### Carbon Dioxide

Carbon dioxide (CO<sub>2</sub>) is considered a utility cost for breweries and is typically purchased through a third-party provider. Carbon dioxide is also a byproduct of the brewing process, which creates an opportunity for a closed-loop system. These CO<sub>2</sub> recapture techniques are often employed by large, regional craft breweries. However, CO<sub>2</sub> recapture technologies can be cost prohibitive for small craft breweries. Through new technology and innovation within the field, a few companies, such as Anton Paar, have created products that allow real-time monitoring of the fermentation process, which gives brewers more visibility and control throughout fermentation. Others, such as CO Brew, have made CO<sub>2</sub> recapture possible for even microbreweries with an annual production of 500 bbl.

GGBC currently uses more CO<sub>2</sub> than the average brewery producing under 1,000 bbl annually at 7.6 lbs of CO<sub>2</sub> per barrel of beer, where the average is 5.6 lbs of CO<sub>2</sub> for every barrel of beer (Fig. 6). By reducing usage at Gilded Goat to reach the average of 5.6 lbs of CO<sub>2</sub> per barrel of beer, an annual cost avoidance of \$297 is possible (Fig. 2). To reduce CO<sub>2</sub> for a small-scale brewery, monitoring and measuring carbon dioxide usage during the various stages of the brewing process is crucial. Understanding the optimal amounts of CO<sub>2</sub> needed to purge the serving tanks and kegs can not only save money but also can promote a safe work environment with less CO<sub>2</sub> potentially leaking into the building. Further, optimizing your CIP/SIP strategy and chemical selection can reduce the need to completely blow off, purge, and repressurize at every cleaning.

GGBC has measured usage for purchased CO<sub>2</sub> in order to better set and attain goals. Since purchased CO<sub>2</sub> was the most in-



**Figure 5.** Gilded Goat Brewing Company's fuel usage (therms/bbl) across the industry based on production size (Brewers Association Benchmarking Tools 2019; reproduced by permission).

efficient utility, the project team worked with a growing company, Anton Paar, to utilize monitoring tools for carbon dioxide, specifically the CboxQC™, which provides real-time CO<sub>2</sub> and O<sub>2</sub> measurements directly from process lines, tanks, and kegs during production and packaging. This equipment was used to determine oxygen levels in the fermenters, brite tanks, and kegs, which provides a better understanding of CO<sub>2</sub> usage in purging the various equipment. This tool has been instrumental in reducing purchased CO<sub>2</sub> at Gilded Goat by 50%. Primarily, the technique used to purge brite tanks was changed to the “low and slow” method (e.g., 5 psi CO<sub>2</sub> into the bottom of the tank for 45 min). CboxQC testing demonstrated a sufficient purge at 30 min for a 7 bbl tank using this method. Additionally, by using the CboxQC to evaluate dissolved oxygen concentrations in finished beer, GGBC was able to change their transfer technique to using a low RPM pump and CO<sub>2</sub> jumper line to move beer, thus only blowing down a single tank at the end of the transfer instead of both the sending tank and the receiving tank.

**Employee Engagement**

Employee engagement is crucial in any business working toward sustainability. GGBC has included sustainability as an important topic in employee training and has worked to instill a culture for sustainability in the workplace. With employees engaged on a basic level of sustainability, the main intervention was educating the employees on various day-to-day tasks that could be slightly changed to reduce energy and water consumption. Having only 13 total staff members made engagement easier and more focused on day-to-day actions, such as only turning on half the lights during the day when the natural light shines in the taproom.

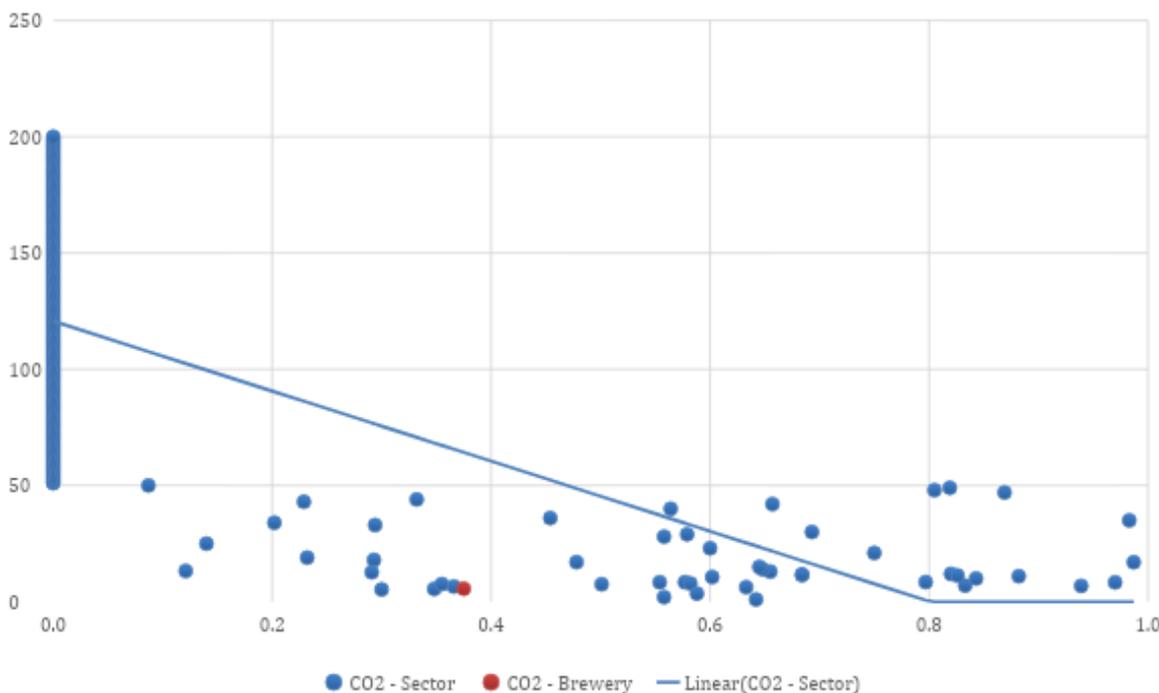
While these simple solutions are helpful and reduce energy consumption and costs, the biggest challenge in employee engagement is creating a company culture in which an environmental mindset is encouraged. It can also be beneficial to in-

clude all employees in efficiency brainstorming. Gilded Goat has employee deep-clean nights during which all the employees come in after close and clean areas that do not often get cleaned. We have also now been using this time to check for leaks and inefficiencies and to replace small things like hoses and small equipment that need regular replacement or maintenance. This allows us to monitor and maintain all aspects of the brewery and engage the staff in various processes within the brewery they are not often exposed to, providing more efficient equipment and better understanding of regular maintenance schedules by employees. Often, employee engagement can be the key limiting step in achieving a conscious improvement together with an economic value, because these employees are often the first to notice maintenance issues and can be empowered to address the need via incentives.

**Community Involvement**

BreWater is a local Northern Colorado organization made up of breweries dedicated to the conservation and preservation of our natural and local waterways. GGBC’s involvement in BreWater allowed the project team to educate other breweries on the project and also learn about their experiences, as well as what they want to do in terms of sustainability and overall utility consumption. The community also hosts an annual Poudre Pub Talk, a series of talks at various breweries focusing on different aspects of sustainability around our waterways. These pub talks lead up to the annual Poudre Heritage Alliance’s Poudre Pour, which is designed to educate the public on our local waterway and why it is important to our community. The breweries are featured to showcase how critical good quality water is, especially for beer.

Beyond using the BA benchmarking tools to monitor energy usage, the project team utilized local programs and free services to better understand the opportunities for efficiencies. One of these programs, Efficiency Works, is a free service provided by



**Figure 6.** Gilded Goat Brewing Company’s purchased carbon dioxide usage (lb/bbl) across the industry based on production size (Brewers Association Benchmarking Tools 2019; reproduced by permission).

the City of Fort Collins in which the city's energy engineer will visit the business and audit the building, operations, and equipment to find opportunities for efficiency, and then they provide various recommendations with associated costs including different rebates the city offers for specific implementations. While this program is incredibly useful, most of the recommendations provided were expensive, and even with a short payback period they were not economically feasible in the near future without extra funding.

### Conclusion

This project was designed to showcase the need for feasible sustainability solutions in the craft beer industry. The project focused on collecting data, benchmarking across industry standards, setting goals, and providing future recommendations for sustainability at GGBC in Fort Collins, Colorado. Through the data analysis and partnership with the BA, standard KPIs were determined and benchmarking goals set. Additional monitoring, data collection, and implementations to determine feasible solutions for energy, water, CO<sub>2</sub>, and waste reduction were established from that assessment. Through city programs, stakeholder input, and employee engagement, we were able to identify key areas of focus—water, electricity, fuel, and CO<sub>2</sub>—to provide the greatest opportunity for short-term environmental and economic savings. The data showed that the electricity and overall energy were contributing the most to the brewery's environmental impact. GGBC has already been able to reduce purchased CO<sub>2</sub> by 50% through monitoring and process shifts, but GGBC does not currently have enough data to see how other KPIs have been affected. Through this data and essentially the initial steps of an environmental management system, GGBC can now establish long-term goals and continue to measure and monitor usage, maintenance equipment, and benchmark across industry standards. While this project does not include all po-

tential solutions, it includes the most feasible solutions based on social, environmental, and economic sustainability for GGBC.

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