EVALUATING QUALITY, ENVIRONMENTAL IMPACT, AND ECONOMIC SUSTAINABILITY PRACTICES IN SUPPORT OF BENCHMARKING EFFORTS AT TWELVE GUNS BREWING

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A Major Qualifying Project submitted to the faculty
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Glossary

Term	Definition
Dissolved Oxygen (DO)	A measure of how much oxygen is dissolved in the water
1 Barrel of Beer	Equivalent to 31 Gallons of Beer
Reverse Osmosis	Process of removing contaminants from water by using pressure
Spent Grain	"Compact waste of malt and/or grain left after mashing in the brew house"
Brite Tanks	Equipment used to clarify and carbonate beer
Carbonation Stone	Vintage technique that consists of a porous stone that slowly diffuses CO2 through beer to carbonate it
Pinpoint Carbonation	Modern carbonation technique that utilizes a flattened nozzle that carbonates beer to a more specific and exact amount
Purging Oxygen	Method commonly used in safety-critical process chambers to eliminate oxygen and moisture that could spoil beer
Capture & Condensate System	Process of collecting hot condensate from steam produced in brewing process to be reused

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Abstract

The goal of this project was to understand the current Quality, Environmental Impact, and Economic Sustainability practices of craft brewers throughout Massachusetts and Rhode Island to assist Twelve Guns Brewing as they plan to expand and scale up their business in 2023. Our team visited multiple craft breweries throughout this region to understand their practices in these three areas. The findings were then shared with Twelve Guns Brewing, where our team outlined the recommendations to improve practices at their new location.

Figure 1: Recent Twelve Guns Brewing Event

Acknowledgments

Throughout the completion of this Major Qualifying Project, multiple individuals and businesses aided us in our endeavor. Our team would not have been able to succeed without the help of the following:

First, we would like to thank Kyle Michaud, founder and owner of Twelve Guns Brewing, for sharing his expertise in the brewing industry to assist with the completion of this project. Kyle provided our team with the necessary knowledge and contacts to visit multiple breweries and understand the important areas to focus on within the brewing industry. Thank you for all your assistance and time spent meeting with our team in the pursuit of this project.

Secondly, we would like to thank our main advisor, Professor Ed Gonsalves of WPI. His contacts and knowledge in the brewing industry were paramount to our team's success while fostering our excitement for learning more about brewing. Thank you for reading the drafts and revisions of our paper, pointing us in the correct direction, and helping us find a project that coupled our interests and our areas of expertise. Thank you also to our co-advisors, Professor Aaron Sakulich and Professor Walter Towner of WPI, for their assistance with reviewing and editing this report.

Finally, we would like to give a huge thank you to all the brewers and employees of the other six breweries we visited throughout Massachusetts and Rhode Island including Scott Drake from Wormtown Brewing, Cullen Dwyer from Wachusett Brewing, Chip Jarry and Mike Gardner from Bay State Brewing, Bryan Dwyer from The Guild, Rebecca and Todd from Pivotal Brewing, and Greg Carlson from Redemption Rock Brewing.

Executive Summary

Project Motivations

The craft brewing industry has been growing rapidly in the past few decades, with smaller breweries popping up all over the United States, especially in New England. Located in Bristol, RI, Twelve Guns is one of these newer breweries. Our team was invited by the founder and owner to evaluate the current craft brewing industry in terms of quality best practices and environmental Impact efforts to assist in their scaling up of a new, significantly larger brewing facility. Through our visits to other local New England breweries, we learned more about how quality is maintained in the industry, focusing on best practices and how quality control is maintained. Throughout our brewery visits we also evaluated the different ways breweries are implementing sustainability in their daily processes. Our team also evaluated the economic sustainability factors of the breweries visited. The goal of the project was to understand the craft brewing industry's best practices and provide findings and recommendations to the owner of Twelve Guns.

Objectives

The project's first objective was to understand the current industry practices in Quality, Environmental Impact, and Economic Sustainability. Our team visited seven breweries throughout New England, collecting relevant data in each of the three categories.

After collecting data from each of the breweries, our team developed a criteria and ranking system for each main category: Quality and Environmental and Economic Sustainability. The Quality, Environmental Impact, and Economic Sustainability criteria were broken up into sections and subsections within each main category, in which each brewery was scored from 0 to 3. A final score was calculated for each of the three main categories, which were then used to calculate one total score for each brewery.

Finally, throughout our research we identified an area of need within the brewing industry regarding accreditation for environmental impact. So, for the final objective, the team outlined a business proposal for an environmental impact accreditation business that visits local breweries and calculates their total sustainability and impact on the environment.

Summary of Findings and Recommendations

While the holistic findings and recommendations are outlined below, please refer to Appendix 1 for the Individual Brewery Findings Reports that the team delivered to the breweries we visited.

Quality Findings & Recommendations

Overall, Twelve Guns scored the highest in quality out of the small craft breweries visited, but the larger breweries outscored them due to available size and resources. The importance of a quality lab stood out in order to achieve reliable and high-quality products. Quality labs with equipment such as forced fermenters and consistent shelf-life testing environments scored the highest. Secondly, it is important to implement a consistent and precise shelf-life testing process to ensure correct and reliable data is collected. Our team recommended multiple shelf-life testing be used at Twelve Guns to further improve quality as well. Lastly, it is important to track dissolved oxygen (DO) levels throughout the brewing process. The breweries that scored the highest in this section monitored the DO level at multiple, if not all, stages of the brewing process.

Environmental Impact Findings and Recommendations

All seven breweries visited partner with local farms to dispose of their spent grain as feed for animals. The team found it is also important to utilize milder chemicals in the cleaning and sanitizing processes. At a minimum, these chemicals need to be diluted before dumping occurs. Carbon emissions and CO2 usage were areas most breweries struggled with, and our team found implementing nitrogen usage in various stages of the brewing process reduces the Impacts for both. Most brewers utilized Pak-Tech tops for packaging four-packs, which are made of dense plastic and are not recyclable in city recycling programs. Only two of the breweries visited utilized cardboard tops, which are a recyclable, biodegradable alternative, one of which was Twelve Guns. Many breweries only track the inflow of water, and our team recommends that both the inflow and outflow of water are tracked, to ensure there are no leaks in the brewing process.

Economic Sustainability Findings and Recommendations

In terms of economic sustainability, the size of the brewery does affect the economic sustainability status, for example expansion. The criteria created by our team can be seen as rather arbitrary and

opinion based, but we believed we set for very solid and nonbiased results for the breweries. A larger brewery would be more likely to be able to expand due to higher revenue streams, while a smaller brewery maybe not have the necessary funds. Social media has proven to be one of the best ways to gain free advertising for any business and all the breweries that we evaluated had a solid online presence. Some of the recommendations that our team made, especially to smaller breweries is to work with other breweries/businesses to create partnerships and gain consumers that way, along with continuing to grow their social media accounts and merchandise options.

Introduction

Craft brewing has grown exponentially in the past few years, especially across New England. But with this industry growth it is important for brewers to pay attention to the quality of their products, environmental Impact of their facility and processes, and economic sustainability of their business overall. Twelve Guns Brewing has continuously done all three of these and invited our team to continue this process with them. Especially in terms of environmental Impact, Twelve Guns strives to have the least environmental Impact, create their own energy, and maintain low carbon emissions. Our team was asked to visit and evaluate other breweries around New England to show Twelve Guns the different best practices and experimentations in place to help improve their overall brewing process.

C Our team created the following three objectives to complete our project:

1. Understand current brewery industry practices in these three categories by compiling data from the Brewer's Association (BA) and by visiting local breweries.
2. Evaluate Breweries' Quality and Environmental and Economic Sustainability by developing ranking criteria for each category and calculating a total score for each brewery.
3. Develop a business proposal and plan for a brewery accreditation service and survey breweries to weigh interest.

This report outlines background on craft brewing, Twelve Guns Brewing, quality in the brewing process, environmental Impact in craft brewing, and areas of economic sustainability to understand. It also details the methods we used to complete our project goal and explains the findings compiled through data collection and ranking. Finally, our team made general recommendations in each of the three main categories for Twelve Guns.

Background Chapter

1.0 Craft Brewing

Historically, brewing beer has been around for thousands of years, with archaeologists finding traces of brewing in Middle Eastern Kingdoms as much as 13,000 years ago in the Jordan-Palestine region. These practices came to the United States with colonization and erupted, continuing to expand through today.

1.1 History of Craft Brewing

Brewing is considered very deeply rooted in many Eastern social Kingdoms including Babylon and Mesopotamia. There were many spiritual rites, ceremonies, and rituals that involved beer, including the offering of it to Mesopotamian deities. This has been documented in letters, tablets, inscribed stones, and more that have been preserved to prove the existence of beer. “Archives contain many details about beer, drinking manners, brewing techniques, and the social functions” (*The Origin of Archaic Beers and the Domestication of Plants. - Beer Studies*, n.d.) of beer in these different regions. Many of these archaeological expeditions have led to a much larger understanding of brewing history across the globe. While wine was considered a luxury beverage drank only by the elite in these times and for many years after, beer was consumed by everyone from common workers up through kings and noblemen. Local economies in Mesopotamian kingdoms and what is now Syria greatly depended on brewing as a crucial cornerstone to their development.

While beer was widely enjoyed in these Eastern kingdoms, the empires of Ancient Greece and Rome preferred wine and never really took to beer. Through the Dark Ages in Europe from 500 to 1000 CE, brewing continued but with very few advancements. During the 1100s European brewers introduced hops into the brewing process, and continued growing Central Europe into a “brewing powerhouse” (Garrett, n.d.) globally. Brewing spread to Germany soon after and in the 1300s, Hamburg, Germany was the brewing center of the world, drafting laws regarding beer purity that are still used in a different form today.

In the late 1500s, Britain sent colonizers to the New World, who brought brewing techniques with them to spread and advance. Soon after the beginning of the colonization effort, the Industrial Revolution in England led to the modernization of brewing practices and the creation of porter beer that was stored for months allowing it to mature without spoiling. All these techniques continued to spread to America, leading to brewing being a large part of the economy in America by the late 1800s. While Britain specialized in brewing ales, America, Scandinavia, and Central Europe mostly focused on lagers.

In more recent years, the Brewers Association of America was created in the 1940s, then called the Small Brewer's Committee. Later in the twentieth century, Jack MacAuliffe of Sonoma, CA opened one of the United States' first microbreweries. This adaptation of the brewing business model was a strong catalyst for the US craft brewing movement in the following decades (*Beer History - CraftBeer.Com*, n.d.).

1.2 Current Craft Brewing Industry Logistics

Today, the craft brewing industry has expanded substantially, taking on many different forms including microbreweries, taprooms, and brewpubs. Brewing in general has seen a rise in sales volume since COVID-19 and is predicted to continue in the future. This chapter discusses the current statistics of the industry, their market segments, and the logistics of craft brewing.

1.2.1 Craft Beer Industry Market Segments

A craft brewer is defined as "a small and independent brewer" ("Craft Beer Industry Market Segments," n.d.) and the craft beer industry is broken up into six market segments by the Brewers Association including: microbreweries, brewpubs, taprooms, regional breweries, contract breweries, and alternating proprietors ("Craft Beer Industry Market Segments," n.d.). The former three are important to this project, whereas the latter are larger and not generally affected by the smaller breweries.

A microbrewery is a brewery that "produces less than 15,000 barrels of beer per year" ("Craft Beer Industry Market Segments," n.d.) and is the smallest brewery segment. These breweries sell at least 75 percent of their product off-site through wholesalers and retailers. There are three main methods that these microbreweries use to sell to the public. The first is the traditional three-tier system, which consists of the brewer selling to a wholesaler, who sells to a retailer, who sells to a

consumer ("Craft Beer Industry Market Segments," n.d.). The second is the two-tier system where the brewer acts as the wholesaler to cut them out of the process. And finally, they can sell direct-to-consumer by allowing them to carry-out or through on-site taproom and restaurant sales.

Brewpubs are considered restaurant-breweries that sell at least 25 percent, if not more, of their products on-site while also operating food-service options. Primarily, the beer is brewed for sale in the bar or restaurant, and when it is allowed, they sell beer to-go or distribute it off-site. The laws on off-site distribution differ by state, which impacts their sales ideas.

Taproom breweries are similar to brewpubs including the amount of beer sold onsite, over 25 percent, but unlike brewpubs, they do not have food services. Some of these taprooms invites food trucks to sell on their property for events or allow customers to bring their own food to eat while enjoying their beverages. Their products are mostly brewed to be sold in the taproom, and again like brewpubs, sell beer to-go and have off-site distribution where it is legal. Brewpubs and taprooms are specifically appealing to consumers because they often "dispense their beer directly from the brewery's storage tanks" (*Brewery, Microbrewery, Brewpub. What's the Difference?*, 2016).

Regional breweries produce between 15,000 and six million barrels of beer per year, much larger than the traditional craft brewery. Some smaller craft breweries are contract brewers that hire other, often larger, breweries to produce beer for them because they do not have the space. Finally, alternating proprietors are tenants that share brewery space. These three market segments are much larger than the scope of this project, and therefore will not be evaluated.

1.2.2 The Brewers Association

The Brewers Association (BA) is a not-for-profit trade association that became an official organization created from the original Small Brewers Committee of the mid-1900s. The purpose of the BA is "to promote and protect American craft brewers, their beers, and the community of brewing enthusiasts" (Brewers Association, n.d.) by promoting brewing best practices, researching trends throughout the industry, and educating brewers on how to improve their business. The BA creates annual reports to display statistics and trends of the brewing industry each year.

The BA's mission is to provide all the resources a small brewer might need to grow and hone their craft along with the community to support them. As a member of the association, brewers have

access to thousands of documents and data collected relating to all areas of brewing. They want to make sure that the art of brewing is maintained for generations to come, and all members are supported within the brewing community. The BA has also supported the creation of regional and state-based brewers' organizations. One example of these is the Massachusetts Brewers Guild that is in place to act as a smaller and more local version of the Brewers Association.

1.2.3 Current Craft Brewing Industry & Demand Statistics

Since the COVID-19 pandemic, all areas of food and beverage sales have been recovering, including breweries, returning to their traditional or even new models of business. Due to the supply chain challenges post-pandemic, many breweries had slower rebounds, trying to experiment with new ways to circumvent these issues ("State Craft Beer Sales & Production Statistics, 2021," 2022).

Nationally, the volume of craft brewing sales grew eight percent from 2021 to 2022. In 2021, there were 3,708 taprooms operating in the US, making up the largest segment of the craft brewing industry (*The New Brewer May/June 2022*, 2022). In the Northeast region, Tree House Brewery in Massachusetts was the largest individual taproom, selling 40,000 barrels of beer in 2021. While New England is a region densely filled with craft breweries, the actual distribution of breweries differs by state. Overall, Massachusetts' craft brewery industry is massive, totaling 194 craft breweries in 2021, compared to only 45 a decade earlier. Figure __ below outlines these statistics and more based on per capita.

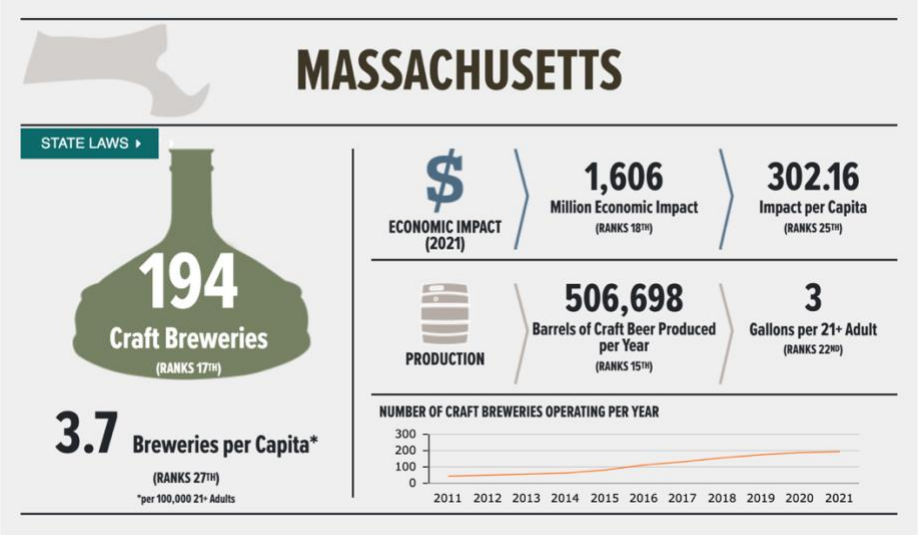

Figure 2: Massachusetts Brewery Statistics ("State Craft Beer Sales & Production Statistics, 2021," 2022)

While Massachusetts has experienced steady craft brewery growth over the last few years, the state of Rhode Island craft brewing numbers shot up significantly in 2017 and have relatively steadied since. In 2021, there were 37 craft breweries, ranking 45th out of all US states, compared to 20 in 2017. The smaller number of breweries in Rhode Island does mean less competition within the state, but many breweries aim to sell across state lines throughout the region of New England, so they still face the competition of larger breweries in Massachusetts and farther north in Maine, New Hampshire, and Vermont. Figure 3 below outlines Rhode Island's craft brewing statistics found by the BA. According to the Brewers Association, there were a total of 665 operating craft breweries throughout the six states that comprise New England - Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut ("State Craft Beer Sales & Production Statistics, 2021," 2022). This number is predicted to increase as breweries continue to grow and pandemic worries decrease.

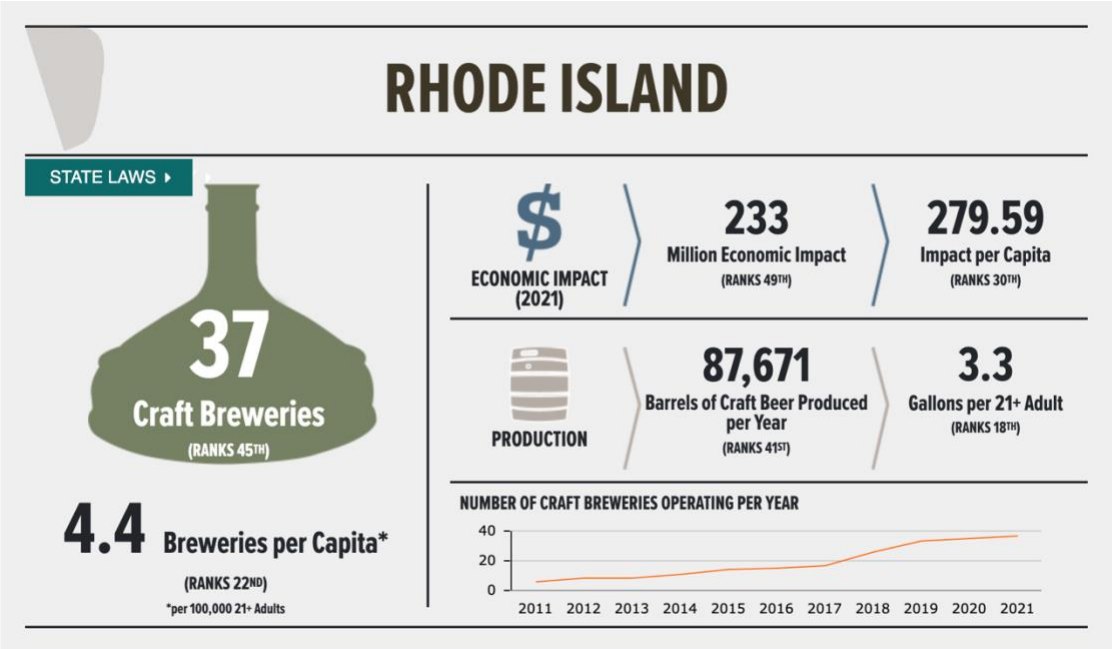

Figure 3: Rhode Island Brewery Statistics (Zotero)

Volume production in microbreweries from 2020-2021 increased by eight percent, showing a rebound from the pandemic and hoping to increase in 2022 and beyond (*The New Brewer*

May/June 2022, 2022). The smaller brewery models were hit harder by the pandemic due to the in-person volume of sales but are seeing an uptick in consumer visits onsite recently.

1.2.4 Future Predications for Industry Trends

The craft brewing industry continues to expand, and brewers are constantly following trends throughout the industry and experimenting with new products. One of the largest trends currently is the growth in popularity of sour beers. This style of brew is unique and an often-niche product, but they have become much more mainstream and "are outperforming other beers as far as growth" throughout the year (*Craft Beer Marketing & Industry Trends Shaping 2023 By Linchpin*, 2020). In part this explosion of performance is due to the growing selection of sours and diversity within the category. This trend is expected to continue into the next few years as well.

Since the pandemic, there has also been a growth in non-beer alcoholic beverages including hard seltzers and ready-made cocktails. In 2021, hard seltzers captured almost ten percent of the US beer market and large retail brewers are continuing to sell seltzers with great success (Arthur, 2021). This has caused craft brewers to edge into the market creating their own takes on seltzers. While this is promising, constant changes within the consumer environment makes it difficult to predict with certainty what the "long-term sustainability of products like hard seltzer, ready-to-drink cocktails, and other 'fourth category' beverages" will be (*The New Brewer May/June 2022*, 2022). But many craft brewers are expanding their products to experiment with these newer beverage options.

1.3 Twelve Guns Brewing

Twelve Guns Brewing opened in October of 2019 in Bristol, RI. According to their mission, the environmental Impact of the brewery was the main concern when developing their business plan, with their goal to create a sustainable company that produces high quality products that keep customers coming back for more (Twelve Guns Brewing, 2021). Since opening, they now distribute their products throughout Rhode Island and in 2023 are opening a new larger location in Bristol, RI. There are always eight beers on tap in a variety of styles that are constantly rotated with new and seasonal products (*Twelve Guns Brewing*, n.d.). Along with alcoholic beverages, Twelve Guns offers non-alcoholic drinks including club soda, and invites local food trucks to set up outside the taproom and feed customers.

Since their opening, Twelve Guns has strived to be as environmentally friendly as they could be, to disprove the common belief that breweries are horrible for the environment. In February of 2021, two years after opening, Twelve Guns introduced cardboard packaging for their four-packs, a more sustainable alternative to rigid plastic packaging. Later in March 2021, they also announced their building relied completely on energy produced by the solar panels on the roof of the taproom. In addition, Twelve Guns utilized a recapture system that captures condensate from the steam produced in the brewing process to be reused as water in the cleaning and cooling processes. All these efforts help to offset the negative effects of the brewing process on the environment around them.

The taproom environment of the current Twelve Guns location is small but welcoming. The brewing equipment can be seen from the taproom seating, which is a favorable aspect for customers. Many events are hosted within the taproom and on the patio outside in the warmer months including trivia, live music, and sports viewing parties. As Twelve Guns moves to their new location, they plan to include even more amenities including a bowling alley and games such as cornhole and shuffleboard.

Figure 4: Twelve Guns Brewing Taproom (Twelve Guns Brewing, 2022)

Twelve Guns has started growing and diversifying, building a distribution company within the brand and expanding into non-beer products. Currently, their most popular beers are brewed at another larger brewery because their small brew house cannot support the demand. With the new location set to open later in 2023, this outsourcing of production will not continue, with Twelve Guns brewing all their products onsite. This will also allow them to become a contract brewer for other small breweries that are just starting out.

Twelve Guns expanded their product offerings in May of 2020 with the introduction of their seltzer sister company, Cannon & Anchor. Due to the growth in demand for seltzers during the COVID pandemic, this brand has been largely successful, winning first place in can design and 2nd place in overall experience at the Seltzerland Festival in Boston, MA in August of 2021. Kyle has expressed interest in experimenting with Ready-To-Drink (RTD) cocktails but anticipates difficulty maintaining quality with these different products.

Figure 5: Cannon & Anchor Brand (Twelve Guns Brewing 2021)

2.0 Quality Standards

There are many aspects of brewing that go into creating the perfect beer. Everything from the equipment used, to the raw materials sourced, to the quality standards in place all affect the end

product's quality, taste, and appearance. Implementing strong quality standards that encompass all these areas of brewing is crucial to creating a successful product.

2.1 Quality Requirements

Good Manufacturing Practices (GMPs) are the core of quality in any industry that produces food, a category that beer falls under in terms of regulations. GMPs are regulatory requirements that are set and specified by regulatory agencies such as the FDA (BA Quality Labs video). Not complying with GMPs means that these agencies can consider the beer produced to be "adulterated" or "contaminated," which could Impact sales and consumer purchasing.

2.2 Supplier & Raw Material Quality

Another important standard is supplier and raw material quality. There are many materials that are used within the brewing process, all of which greatly impact the final product's quality. "Carbon dioxide (CO2) is a crucial process aid and ingredient in beer production" ("Brewing CO2," 2021). The quality of CO2 is managed by the supplier generally, but it is important for brewers to do their own research on the supplier to ensure the quality of gas is up to their standards. Brewers also need to be aware of how CO2 is handled throughout the brewing process, because as a compressed gas it can be deadly. There are various regulatory agencies that control purity standards for CO2 including the Compressed Gas Association (CGA), International Society of Beverage Technologists (ISBT), and the US Food and Drug Administration (FDA).

Water is a crucial ingredient in the brewing process and can greatly affect the quality of the product. Scientifically, there are five main ions that affect the flavor of beer including "Calcium, Chloride, Magnesium, Sodium, and Sulfate" (Helf, 2019). The amount of these ions and the hardness or softness of the water differs greatly by location. Tracking these statistics within the water that is sourced by a brewery is very important to understand how it will affect the brewing process. As different styles of beer need different compositions of water, brewers can alter the water breakdown to create the desired style of beer. For example, the water table of Germany is ideal for creating an Oktoberfest beer, traditional to the Bavarian region. Brewers in the United States can replicate the composition of German water by using reverse osmosis. This process can ensure the style of beer brewers are aiming for is high quality and boasts proper composition.

2.3 Quality Control & Labs

One way that many brewers ensure their products are up to quality standards is by implementing quality control regulations throughout the brewery and the brewing process. Dedicating a specific set of the brewing team to focus specifically on quality is the simplest way to achieve this. These teams can establish regulations that are tested and checked in each step of the brewing process to ensure that the process is consistent and produces high quality beer. Consistency is very important within the brewing process because loyal customers will keep returning to a brewery to purchase their favorite beers. If the flavor or appearance of the beer is not consistent, customers might be deterred from returning and not become the loyal customer base that every craft brewery desires.

Brewpubs and taprooms also have started implementing quality labs within their breweries to monitor quality and experiment with new products and techniques. Recently, the Brewers Association has held workshops for smaller microbreweries to improve their quality standards without having to pay the exorbitant prices for high-tech equipment in an official lab setting. These labs can help calculate the pH and gravity of the beer, ensuring that each batch is reaching the predetermined levels. Labs also monitor bacteria within the brewery equipment and the batches themselves.

3.0 Environmental Impact

Sustainability is a goal strived for with the overall message that humans need to coexist with the surrounding environment. It is a way of actively taking care of the present while better ensuring a positive future.

3.1 Social Push Towards Sustainability

In today's world, the importance of businesses operating environmentally/ecofriendly is growing substantially. Meeting the sustainability requirements and or general goals is anything short of easy. “According to ENGIE Impact’s analysis of CDP reporting data, only 15% of food & beverage companies reporting to CDP are on track to meet their sustainability goals,” (*Food & Beverage Industry Sustainability Strategy*, n.d.). In order to meet evolving consumer needs and interests, businesses will have to put more of their attention on this social push. Sustainability can

relate directly to the success of a company depending on the consumer and their preferences. A recent study from 2018 showed that most US beer drinkers would pay roughly $1.30 more per 6 pack for sustainably produced beer over beer produced in an unsustainable manner (Dingwall, 2021). Not disclosing sustainability statistics can also affect a brewery's sales as consumers are highly interested in this information. “Globally, 85 percent of people indicate that they have shifted their purchase behavior towards being more sustainable in the past five years,” (Pope, 2021). There also tend to be more regulations and codes related to the environment that need to be met for companies to operate. These rules often differ by location, often decided on a state, county, or even city level. Consumers often pay attention to how the environment around them is being affected, which can influence decision making.

3.2 Sustainability in the Brewing Process

One way the Brewers Association began evaluating sustainability was through implementing sustainability programs and benchmarking tools. These benchmarks help to assess standards, certifications, and identify any weak spots in the process (Brewers Association, n.d.). The biggest problem faced by breweries is how to deal with the wastewater. With water making up more than three quarters of beer there tends to be a lot of excess material throughout the process. As a brewing company you cannot just discard the wastewater due to regulations. These rules differ by town and or city. What the brewery chooses to do with the wastewater needs to be closely monitored and tracked by the company. There are a few ways to properly recycle wastewater, but techniques may differ depending on the scale of the brewery or the equipment at hand. Some breweries store their wastewater in holding tanks to complete settling and chemical analysis to ensure that the wastewater being dumped isn’t toxic or dangerous to the surrounding environment (Dingwall, 2021). Others reclaim the wastewater through a filtering process and use it to water their plants and home gardens; while some have even started to create beer from the filtered out, clean wastewater so it does not even go to waste or enter the environment (Dingwall, 2021). Some smaller breweries choose to deliver their spent grain to local farmers which is as good for the environment as it is for the farmer. These practices take a lot of time and energy on top of the brewing job itself, so companies are always looking for new easier/quicker ways to aid their sustainability process. Finally, using less harmful chemicals in the sanitation part of the brewing process is another way to increase sustainability. These more neutral chemicals allow for the

wastewater to not be toxic for the environment when it is properly disposed of. This is crucial to the city and town of operation because if the waste is seen as non-harmful by the citizens and it helps the overall sustainability process it will help drive the business.

3.3 Sustainable Suppliers & Raw Materials

The issue for smaller craft brewers in this scenario is that most of the time they do not have the capital to implement large sustainable practices. A more cost-efficient approach to this problem is to support local farmers by sourcing raw materials from them. This practice helps support the local economy, the farmers, and can decrease the carbon footprint as local deliveries require a much shorter travel distance (Dingwall, 2021). This is not the only answer to the sustainable practice issue for small brewers, but it is a start.

3.4 Sustainability in Packaging

A lot of materials are used in the packaging process, so disposal requirements are something that need to be researched and factored into packaging practices. Companies are being encouraged to move away from non-environmentally friendly materials like plastic. Pak-Tech tops are the most popular plastic holding containers for six packs and are constructed from rigid plastics which cannot be recycled by using traditional city recycling programs. The amount of waste differs from each brewery depending on size. Cardboard is now finding its way into packaging for four and six packs. Instead of using plastic to hold the cans together at the top, cardboard is now being used because it is more environmentally friendly, and it is becoming economically feasible. These are referred to as The Eco Six Pack Ring or E6PR. The E6PR is comprised of wheat and barley waste from breweries along with other compostable materials and is biodegradable. For reference a plastic ring carrier takes roughly 450 years to properly decompose while these are in fact biodegradable. There have even been a few companies experimenting with glue in between the cans to hold them together so no material is needed. The final aspect of packaging we saw impactful to the environment is the use of canned beverages vs bottles. Overall, cans are a better alternative to bottles in a few aspects. Canned beverages provide a better seal than glass to prevent spillage, and leaks of carbon dioxide which is essential to the brewing process. Cans are also lighter in weight which results in easier shipping methods. This is very important when dealing with large

quantity orders. Finally, recycling is easier with cans since 100% of aluminum can be recycled vs bottles and the risk of the bottle breaking in the process.

Figure 6: Cardboard can carriers (Twelve Guns Brewing, 2021)

3.5 Cost of Environmental Impact

Sustainability is often an expensive practice but a necessary one. Some factors that drive the cost of this practice are demand and the cost of raw materials. As a result, "the cost of sustainable products is often higher than conventional products due to expensive raw materials. These premium raw materials are necessary to produce a product that has a lower environmental Impact," (Ofei, 2023). Overall, an environmentally sustainable brewery is going to cost more money and requires more planning to layout the operation. This is more difficult for smaller craft breweries better known as microbreweries, taprooms, or brewpubs because they generate less revenue. The equipment for proper sustainability is expensive and can force smaller breweries that do not have the financial capital to spend on all the equipment they want. Since consumers are becoming more aware of the products they buy and are beginning to support more eco-friendly companies, breweries may be forced to invest. As a result, there will be more of a demand for the product which in the end should positively Impact revenue.

4.0 Economic Sustainability

Economic sustainability is the idea of being able to utilize financial and economic resources to create long-term financial stability. It gives business owners a chance to evaluate their business structure from an economic standpoint.

4.1 Economic Feasibility in the Brewing Industry

Economic feasibility is one of the more important factors for every business to understand, especially those in the food and beverage industries. According to a study from Craft Brewing Business, failure rates for microbreweries are about 24%, while failure rates for brewpubs are just short of 50%. These numbers favor brewers, compared to a 60% failure rate of restaurant owners for reference (*Beer History - CraftBeer.Com*, n.d.). When opening a brewery, most sales in the first few months must go immediately into reinvestment to pay for the expensive equipment necessary for large scale brewing. Fermentation tanks, brite tanks, labeling machines, serving and store equipment, sinks and plumbing, and office equipment are just the beginning for costs that will come when trying to start a brewery. Brewing at a large scale can get very expensive very quickly.

4.2 Industry Practices

A mainstay in the brewing industry is being able to make your brewery standout in an industry that is very dense and overpopulated, whether it be unique drinks, popular entertainment, tactical themed nights, or other aspects that can make a brewery standout. Some common practices include ideas such as trivia nights, which give consumers an opportunity to compete to earn a sponsored prize, as well as give an incentive for customers to show up on a consistent basis. Another practice is to have classic games such as cornhole, which give consumers an opportunity to interact while doing something they enjoy. The more successful breweries are those that can build a loyal customer base and have a friendly culture that encourages consumers to keep going back. The layout of the brewery needs to not only be appealing to the eye but have a welcoming and exciting atmosphere as well. Especially now more than ever, breweries are showing off their brewing and fermentation tanks as an aesthetic, meaning that every tank needs to be cleaned and washed daily to make sure it is sanitized and looks pleasing to the eye.

4.3 Opening and Operating Costs

Operating and opening costs are two of the most worrying thoughts for potential new owners. When opening a microbreweries or even small operation, it can cost over $250,000. Larger breweries can be upwards of $2,000,000 (*How to Start a Brewery*, 2020). Some of the more significant expenses come from fermentation tanks, brewing machines, maintaining staff, and rental costs.

4.4 Operational Strategy

Operational strategies are vital to any brewery's success. An important element of operational strategy is how the brewery and its products are marketed. Being active on social media, word of mouth and promoting new events can all be effective techniques to retain and find new customers. Another operational strategy that breweries use is contract brewing. Contract brewing is an arrangement between two breweries in which one brewery will send their products to another brewery to both advertise and generate revenue from their product (Arthur, 2021). No two contracts are the same, but many breweries see this as an opportunity to both expand and advertise. An alternative for microbreweries and taprooms is to turn into a brewpub and serve food along with their beverages. This of course changes the companies' tax regulations but also gives consumers a reason to show up at any time. It is a great alternative to get out of the crowded brewing industry while still maintaining that brewery feel. Brewers even create and put meals on their menus that pair with specific beers to try and enhance the overall flavor of both the meal and beer. The main issue is that a transition from a microbrewery to a brewpub is not a simple one. There are legal constraints that need to be satisfied and the brewery owner basically turns into a restaurant owner as well.

Lastly, merchandise is a great way to both create revenue and advertise through customers. Brewery merchandise is often sought upon aspect of brewing by consumers, and can often be creative and stylish, likely because they leverage the imagery from their can designs. These clothes can help noncustomers raise questions about not only the merchandise but the beer as well. This helps to get people talking about the beer providers and business and could attract new customers.

Chapter Two: Methodology

This chapter discusses the methodology that our team used to achieve our project goal. First, we detail our process for understanding the current industry practices in New England breweries, including Twelve Guns Brewing, in the categories of quality and environmental Impact. Then, we outline the system we used to evaluate all the breweries, distinguishing the categories and ranking system we used.

1.0 Project Goal

The goal of this project was to understand the current Quality, Environmental Impact, and Economic Sustainability practices of craft brewers throughout Massachusetts and Rhode Island to assist Twelve Guns Brewing as they plan to expand and scale up their business in 2023.

2.0 Project Objectives

1. Understand current brewery industry practices in these three categories by compiling data from the Brewer's Association (BA) and by visiting local breweries.
2. Evaluate Breweries' Quality and Environmental Impact and Economic Sustainability by developing ranking criteria for each category and calculating a total score for each brewery.
3. Develop a business proposal and plan for a brewery accreditation service and survey breweries to weigh interest.

Objective 1: Understanding Current Brewing Industry Practices

Including Twelve Guns, our team visited seven breweries throughout Massachusetts and Rhode Island. Our goal was to understand the different industry standards that are being utilized throughout the region. To supplement the information that we received from onsite and virtual visits with breweries, we reached out to the Brewers Association to provide us with documentation detailing current industry practice that they track across the country. All of these gave us a well-rounded picture of the current industry in the areas of quality and environmental Impact. Figure 7 below shows the general location of the breweries the team visited.

Figure 7: Map of Breweries Visited

Quality Standards in New England Breweries

Throughout the craft brewing industry, quality is one of the highest priorities. It can greatly affect many different aspects of the product including taste, aroma, and appearance. Consistency in brewing is important because it brings customers back when they find a product they love, so changes in these different areas can deter customers from returning and being repeat purchasers.

We visited breweries and met with head brewers or someone on the brewing team who could talk to the quality practices in place. Our goal was to see firsthand the quality practices in place and discuss how the different locations understood quality. We broke our quality questions into four main categories: quality of raw materials, quality throughout the brewing process, quality labs, and canning and packaging quality. Throughout the brewery tours, we went through the checklists making sure to ask multiple questions in each section. A sample of these questions is shown in Table 1 and the full list of the quality questions are in Appendix A.1. While we asked mostly scripted questions, we would also let the conversation go in the direction the brew master wanted it to. Ultimately, we aimed to understand the different areas of quality practices in breweries throughout the region, looking at every material and step of the brewing process from start to finish.

Quality Lab	Is there a quality lab within the brewery?
	What equipment and tools are used in the quality lab?
	Is shelf life tracked? If so, how?

Table 1: Sample Quality Questions for Breweries

Environmental Impact Practices in New England Breweries

Throughout our brewery tours, we aimed to understand any practices that were put in place or that breweries were planning to implement to improve their environmental Impact. While each brewery operates a little bit differently the end goal in mind with regards to sustainability is the same. We noticed some techniques that were fluent throughout the business while we also saw unique methods used separately depending on certain factors described to us.

Our team developed a list of scripted questions regarding environmental Impact practices that we asked brewers on our visits. Similar to the quality practices, we broke up the questions into four main categories: raw materials sustainability, brewing process sustainability, environmental packaging, and sustainability of waste management techniques. These four subsections had multiple questions in each. A sample of these questions from the raw materials sustainability category is shown in Table 2 and the full list of questions is in Appendix A.2. Depending on the equipment on hand, we would sometimes be shown how process worked with visual representations or actual real time operations which added to our insights from the answers we received from questions.

Raw Materials	Are raw materials sourced locally and from sustainable sources?
	Is inflow & outflow of water tracked?

Table 2: Sample Environmental Impact Questions for Brewers

Economic Sustainability in New England Breweries

Due to confidentiality, our team relied on reviewing the Brewers Association's sources and data on the economy of the brewing industry for this metric. Our first visit to Twelve Guns Brewing

provided an understanding of their specific economics, and also proved helpful for our research. Our focus was to understand the major contributors to financial success, including business and marketing strategies. Some factors included their social media presence and merchandise options, the quality and diversity of the offerings at the brewery, whether they were a contract brewery for other small brewers, and their adaptability to new markets. Our team did not compile an official list of questions to ask brewers about their economic sustainability, but we did use the tours to observe different aspects of their taprooms, beverage options, and overall environment for customers. While talking with brewers, we did ask their opinion on the divergence of the industry into hard seltzers and ready-made-cocktails to understand how they thought consumer demand was going to change in the future. By using the information collected from onsite visits, and the data received from the BA, our aim was to provide an understanding of the economic sustainability of breweries throughout New England, specifically Twelve Guns Brewing.

Objective 2: Evaluating Breweries' Quality, Environmental Impact, and Economic Sustainability

Our team created a ranking system to evaluate breweries for the second objective within the three main sections we focused on. These sections were broken up into subsections in which our team ranked every criterion to calculate a total score in each section and overall, for every brewery we visited.

Category Division & Criteria

To give provide an overall understanding of each brewery, we broke each of the three main categories down into subsections of individual criterion. Within the quality practices section, we identified four subsections including: quality lab, raw material quality, process quality, and packaging quality. Each of these subsections had specific criteria to be ranked. Similarly, within the environmental Impact section there were four subsections including: raw materials, brewing process, packaging, and waste management. Finally, within the economic sustainability section, there were only two subsections: marketing and other. The other section had criteria that did not warrant their own subsection and were grouped together. These three subsections made up the three areas of focus that our team evaluated. The divisions of sections and subsections and their criterion are outlined in Tables 3, 4, and 5 below.

Quality Practices	
Category	Criteria
Quality Lab	Quality Lab
	Shelf-Life Testing
	Bacteria/Spoilers Testing
Raw Material Quality	Sourcing of Raw Materials
	Sourcing of Water & Modification
Process Quality	Carbonation Technique
	DO Level Tracking & Maintenance
	Purging of Oxygen
Packaging Quality	Tracking of Fill Level & Package Quality

Table 3: Quality Practices Categories & Criteria

Environmental Impact Practices	
Category	**Criteria**
Raw Materials	Sourcing of Raw Material
	Raw Material Packaging
	Yeast Usage
Brewing Process	Recycling Practices
	CO2 Usage
Packaging	Sustainable Packaging
	Packaging Recycling
Waste Management	Spent Grain Disposal
	City Dumping Requirements
	Chemical Usage
Water	Inflow/Outflow Tracking
	Recapturing/Reusing

Table 4: Environmental Impact Practices Categories & Criteria

Economic Sustainability Practices	
Category	**Criteria**
Marketing	Social Media
	Merchandise
	Artistic/Unique Can Design
Other	Partnerships/Contract Brewing
	Distribution
	Adaptability to New Markets
	Unique Offerings

Table 5: Economic Sustainability Practices Categories & Criteria

Ranking System

After diving up the criteria into sections and subsections, our team ranked each criterion. The ranking system developed was a team decision with the input of our advisor, and the research compiled from the Brewers Association country-wide data. In order to have a uniform understanding of each of the ranking options, we created a criteria matrix outlining what each level represented for each subsection. We decided that each criterion would be ranked on a scale of zero to three, with each number correlating to a written meaning for the rank. An example of this description is shown in Table 6 below.

Waste Management	**Spent Grain Disposal**	0	Grain is seen as waste
		1	Grain is sent to a local farm within a 150-mile radius with little regard for carbon emissions or composted
		2	Grain is sent to a local farm within a 75-mile radius to try to keep carbon emissions relatively low
		3	Grain is sent to a local farm within a 25-mile radius to ensure carbon emissions are at a minimum
	City Dumping Requirements	0	City requirements are not met and waste is disposed of unethically
		1	City requirements are not met but waste is disposed of ethically
		2	City requirements are mostly followed, and waste is disposed in an ethical way
		3	City requirements are followed perfectly, and waste is disposed in an ethical way

Table 6: Sample of Criteria Matrix for Waste Management within the Environmental Impact Category

After outlining the specific standards for each ranking level of each criterion, our team split up and ranked each brewery on this scale individually using the template shown in Table 6, to ensure there was no bias produced from ranking it together. Then we discussed our individual rankings and calculated a total ranking for each brewery in each category. We decided that if two or more of the team members had the same ranking, that ranking would be the team ranking. If none of the team members individually ranked the criterion the same, the team would discuss their reasons for ranking and decide on a final ranking together. Once all quality criteria were ranked, the team calculated the breweries total score for each category and added the scores up into one overall score for each brewery.

Objective 3: BREW-TRAQ

Throughout the team's research on brewery sustainability, we found that there is not a single accreditation service for breweries in the areas of quality and environmental Impact. In many industries outside of brewing, accreditation bodies provide services for a fee to determine the environmental Impact of companies. These accreditations prove to customers that they are sustainable businesses that are cognizant of their environmental Impact and are striving to minimize it. We recognized a need within the industry to prove to customers and investors that a

brewery is environmentally sustainable. As a result, we decided to develop a business model for a brewery sustainability accreditation business.

Breweries Before Evaluation

With just a quick Google Search of "Are breweries sustainable?" it appears that there is a perception brewing is not considered to be a sustainable or environmentally friendly practice. According to studies from the University of Vermont, it can take up to six barrels of water to produce one barrel of craft beer (Dingwall, 2021). With all the boiling processes needed in the brewing process, lots of water is lost through steam. Brewing is also an energy intensive process, as you need energy to run the entire brewing process.

Breweries Post-Evaluation

After evaluating close to a dozen breweries in the New England and New York areas, our team concluded that most craft breweries understand the negative effects of their breweries toward the environment and are working endlessly to try and restructure their industries to make craft brewing sustainable. We found that farmers have benefited from breweries as every brewery that we visited sent their composted grains to local farmers to feed their wildlife. That is just a small example of what breweries are doing to fight off the stigma that they are harming the environment. Breweries and brewery owners deserve an opportunity to show that they are battling that stigma, that opportunity comes in the BREW-TRAQ Accreditation business model shown below.

BREW-TRAQ Accreditation Business Model

In a study conducted by NPR, it stated that consumers are willing to pay more for sustainable beer (Cohen, 2018). Based on our efforts with this MQP and this additional market research, we developed a brewery-specific accreditation service to help breweries promote their quality and environmental Impact. Consumers had stated in the NPR study that they were willing to pay $1.30 more per six pack if they were sure that the beer was quality tested and environmentally sustainable. $1.30 is not a small sum of money when you consider that the average six-pack of craft beer is around $9.50 nationally. This results in a cost of $10.80 or a 12% increase. It is apparent in this industry that companies would benefit from having some type of accreditation or

third-party approval that their beer is of the highest quality, and they follow strict environmental Impact regulations.

Business Overview

BREW-TRAQ Accreditation would offer breweries a service that would allow them to demonstrate to themselves, their competitors and their customers that they are meeting the need to be a sustainable business. This accreditation will let customers know that they are drinking a great beer that is a tested, quality-controlled product that has a beneficial Impact on the environment. For a reasonable fee, BREW-TRAQ will evaluate both quality control and environmental Impact of their entire brewing process and provide grading of the operation and recommendations for improvements. The brewery will be given a certificate, similar to a health inspector test, if it meets all the requirements for accreditation. and a certification that can be used to promote their brewery to all.

Challenges	Goals and Objectives
Proving that our research and calculated standards demonstrate a brewery that meets high sustainability standards.	To have breweries understand the importance of high quality and environmental Impact to customers.
Expanding the name and image of our company.	Find high end breweries who care about quality and environmental Impact as much as we do.

Table 7: Challenges, Goals, and Objectives of BREW-TRAQ Model

Unique Selling Point:

The accreditation is focused on measuring quality and environmental competence and would be the first brewery-specific accreditation service in the market. It provides owners the opportunity to prove that they are top class in their industry and gives customers the opportunity to take pride in what they are drinking. The success of BREW-TRAQ Accreditation will mirror the continued growth of the brewing industry.

Key Partners:

Ideally, we need the opportunity to work with a larger, more notable brewery who takes pride in their quality and their carbon footprint. Landing a notable brewery would provide us the opportunity to expand and keep improving the overall quality of beer and sustainability to move the industry further.

Key Activities:

The key activity for this business is going to be evaluating the breweries and grading them based on our researched and calculated grading scale. Ideally if the brewery is a top-of-the-line business, then they will receive our accreditation. We will also be giving breweries a detailed breakdown of their score with improvements and recommendations to help them improve for their next usage of our service.

Value Proposition:

The accreditation is going to hold value in the brewing community. Sustainability is becoming a more and more important conversation around the globe. Our accreditation will give value to more breweries and give them a chance to show their community that they are a top-of-the-line establishment. It also gives the consumers the ability to assure that the companies quality and sustainability live up to their claims. Lastly, the brewery would have the option to be posted on our Instagram and post on their own as well to show all users about their successful quality and sustainability.

Marketing:

After accrediting top breweries in the area, other breweries will look to follow in their footsteps and pursue the same type of practices to help promote their own brewery. This accreditation has a chance to help expand the brewing community for the better.

Target Market:

The target market is brewery owners who are looking to prove that their brewery is a top-of-the-line establishment, with a chance to gain bragging rights and an edge on the competition in what is already a very competitive market.

SWOT Analysis

Strengths	Weaknesses
- Promote more sustainable practices in the industry - Encourage reduction of carbon footprint in breweries	- Need to be able to work with a well-respected larger brewery to start - May be challenging to start off the business venture - Need to have large staff based in different regions to cater to more than just a single area of breweries
Opportunities	**Threats**
- Chance to create new universal industry standard in craft brewing - Future partnerships with city/state environmental organizations to provide deductions for certified breweries	- Other non-brewery specific accreditation services - Only able to provide benefit of accreditation in title and nothing more

Table 8: SWOT Analysis for BREW-TRAQ Business Model

Overall Project Limitations and Considerations

Location

One limitation of the project brewery location. While there are a large number within and just outside the Worcester area that we could visit, there were still many more outside the region. Our team had the great opportunity to work with Twelve Guns Brewing in Bristol, RI, but unfortunately, we were only able to visit the site a handful of times due to its distance from campus. Being closer to the brewery would have been a bonus but having Kyle able to respond to communication via email and phone so quickly made up for that fact.

Confidentiality

Another difficulty the team faced was the issue of confidentiality within the brewing industry. Overall, many breweries our team reached out to were more than happy to help us with the project, but there were quite a few that did not want us to visit. They likely did not want outsiders gaining knowledge about their brewing processes as many likely considered their techniques to be trade secret. It was also important that the team did not ask breweries about their financial details

because this is something that companies often keep private. While their financial situation and information would assist our assessment, we knew this would not be openly discussed by the brewers.

Sizing of Breweries and Available Resources

An important consideration while completing this project is the different sizes of the breweries our team visited and how that impacted their resources and scores. It is apparent that the larger breweries with an abundance of resources and money would often score higher than the smaller brewers just due to the sheer size and amount of product prepared. This is why size was noted for all breweries when our final scores were calculated.

Chapter Three: Findings & Recommendations

All the data our team collected while completing our methodology was compiled and led to the final totals for each individual brewery along with general recommendations for Twelve Guns Brewing. The findings were separated into the three categories that were evaluated: Quality, Environmental Impact, and Economic Sustainability. The total ranking of each brewery is shown in Table 9 below, with ranks separated up by the three categories along with total scores.

Brewery	QUAL	ENV	ECON	Total
Twelve Guns (Future)	25	34	20	**79**
Wachusett Brewing Co	26	23	16	**65**
Wormtown Brewing Co	24	22	18	**64**
Twelve Guns (Current)	18	30	15	**63**
Isle Brewer's Guild	22	26	14	**62**
Redemption Rock Brewing	15	25	15	**55**
Pivotal Brewing	16	22	9	**47**
Bay State Brewing	11	20	12	**43**

Table 9: Final Scores of Breweries

Quality Findings

As outlined in our methodology, quality was one of the three main categories our team was evaluating while visiting breweries. Each brewery understood quality as an important aspect of brewing, but handled and maintained it in different ways. Throughout the visits, our team was able to understand these different approaches to quality and how it was ensured throughout the brewing process. The following is the breakdown of our team's quality findings in terms of high rankings and low rankings, meaning strong quality practices and weaker practices.

High Quality Practice Rankings

There were multiple breweries that earned a high-quality ranking, including **Wachusett Brewing**, **Wormtown Brewing**, **The Guild**, and **Twelve Guns Brewing**. All these breweries had a score of

at least twenty points, out of a possible twenty-seven, on our team's ranking matrix. They focused on maintaining a high level of quality by implementing quality control and quality assurance teams and practices and maintaining quality labs on the premises. As pointed out in the project considerations and limitations, the size of the breweries is important to note because this Impacts their overall score as breweries with more products, money, and resources will have access to higher quality equipment and can pay higher premiums for more environmentally sustainable products. So, while there are four breweries out of the seven, we visited that scored high on the quality practice ranking system, only one of those produces less than 40,000 barrels per year, which was **Twelve Guns Brewing**. This is a very telling fact because in 2022, **Twelve Guns** brewed around 1,500 barrels, with an estimated 15,000 that they will brew per year once relocating to their new location. With this upscaling, **Twelve Guns** aims to further improve their quality practices, while still brewing roughly 25,000 barrels less than the brewery with the next best quality score. In terms of small-scale craft breweries, **Twelve Guns** stood out the most with its high-end quality practices and procedures.

Having a quality lab comprised of proper equipment was considered an important criterion by our team. **Wormtown**, **The Guild**, and **Wachusett Brewing** had very big quality labs that were staffed with specific quality control employees who did routine testing and experimenting. While **Twelve Guns** does not currently have a quality lab due to space restrictions in their brewhouse, they have equipment that the breweries with labs have to test quality of their product and aim to build a specific quality lab once they relocate to a larger space in Bristol, RI later in 2023. Within their quality lab, **Wormtown** and **The Guild** utilized processes such as forced fermentation to calculate exactly how long it takes for their yeast to ferment so they can plan the timeline for future batches. This is a helpful process also to ensure that the yeast being used is of high quality and is not compromised in any way.

Shelf-life testing is another important quality measurement within brewing, to ensure that products can maintain their quality while sitting on a shelf for a certain amount of time. Brewers usually aim for the shelf life of beers to be at least a few weeks in cans, but this can differ based on their brewing techniques and the type of beer. **Wachusett Brewing** had one of the top shelf-life testing processes, where samples from each batch are kept in multiple storage conditions, usually cold, warm, and room temp. Then after a certain amount of time, samples are opened and tested in a

double or triple-blind taste test using employees. Tasters are set up in a separate room connected to the quality lab by two sliding windows and all testers compare the samples from each of the conditions to each other and to a sample from a freshly brewed batch. They are looking at not only the quality of the taste, but also the sensory factors involved with brewing which include aroma, color, appearance, head, and more. All feedback from taste testers is written down manually and then entered digitally into their central data storage system. **Wormtown Brewing** has a similar taste testing procedure, where samples from every batch are kept in three different temperature conditions and pulled for employee testing on a regular basis. All testers log their feedback on the digital application that all employees have on their mobile phones. Just like **Wachusett**, everyone evaluates not only the taste of the product itself, but also the sensory experience. While this is more informal of a process and does not have a blind element, it is still a very effective process. **The Guild's** quality team also does shelf-life testing, which they call retain testing, to ensure the shelf life of their product is up to the expected standards. Like both previously mentioned breweries, **The Guild** keeps samples in three different temperature environments for a set amount of time ranging from days to weeks. Quality employees and brewers both test these samples and record their feedback digitally. While they tested taste and sensory quality, **The Guild** also had quality control check the pH and gravity of each sample, just another step to ensure a very high-quality product. **Twelve Guns** uses a less formal process where the brewer stores canned samples from each batch in different temperatures throughout his home and tests them on a regular basis. The only issue our team found with this process is that multiple people do not test the samples which could lead to biased or incorrect conclusion from the one tester.

Within the brewing process, it is important for members of the brew team to test equipment for bacteria and spoilers that could ruin their batches. This is routinely implemented, and regular testing done by swabbing the inside of lines and tanks along with cans before canning. **Wormtown, Wachusett**, and **The Guild** all had perfect scores in the Bacteria/Spoilers Testing category. **Wormtown** and **Wachusett** regularly swab the insides of their tanks and lines between every batch that is brewed to ensure there are no spoilers. **The Guild** has an intense process of testing where samples are taken from every fermenter, brite tank, and a packaged product from each batch. These samples then undergo micro testing for HLP, or *Hsu Lactobacillus Pediococcus*. HLP is a media that encourages the growth of *Lactobacillus* and *Pediococcus* bacteria, which are two of the most common spoilers in brewing (Todd, 2019).

Across the board, every brewery our team visited saw significant emphasis placed on sourcing high quality raw materials. Almost all dry hops were sourced from the Pacific Northwest region of the United States, with wet hops coming from Massachusetts. Some of the larger breweries can visit the hop farms themselves and pick the exact lot of hops they want to use every season to ensure the exact strain they want, but smaller craft breweries often don't have that luxury. They rely on the farmers to ensure high quality ingredients are sent to them, which they usually do not have an issue with. In terms of grain there are two main grain wholesalers in the United States who source different types of grain from all over the world. All breweries rely on these two companies to ensure high quality throughout their supply chain as well. Overall, raw material quality was high for most breweries we visited, with the larger breweries exceeding standards based on their additional resources available.

Many of the breweries we audited did not drastically modify the water they used in the brewing process. Only **Wormtown Brewing** and **Twelve Guns Brewing** achieved a score of three in the water sourcing and modification category. This is because both breweries utilize a reverse osmosis process to change the chemistry and makeup of the water. Because city water or tap water makeup differs from location to location, beers taste different based on the water that is used. Using a reverse osmosis machine can change the chemical makeup of the water to be the perfect formula for the region or type of beer that a brewer aims to produce. This process sets **Wormtown** and **Twelve Guns** apart from the other breweries, who just used the city water.

The most common carbonation technique in brewing is using a carbonation stone. Most of the breweries our team visited utilized this method, scoring a two out of three. **Wachusett Brewing** was the only brewery that scored a three out of three in the carbonation technique area, because of their utilization of pinpoint carbonation to ensure the highest quality and most consistent carbonation possible. Overall, our team found that both pinpoint carbonation and carbonation stones are efficient and high-quality ways of carbonating beverages, with pinpoint carbonation being slightly more consistent.

One of the biggest challenges that brewers face to ensure high quality beer is limiting the dissolved oxygen, or DO, that is in the beer. Throughout the brewing process, beer is transported across many different containers, each stop of which can introduce oxygen into the beer. This is why monitoring DO and maintaining low levels of it are important. **Wormtown** was the only brewery

to score a three out of three in the DO tracking and maintenance criteria. This is because DO levels are checked at every stage of the brewing and canning processes to ensure DO levels are at a minimum. One of the biggest benefits of this is if oxygen is being introduced into the product somewhere in the process, brewers can identify the exact step where this is happening to correct the issue. **Wachusett**, **The Guild**, and **Twelve Guns** all scored two out of three in DO tracking criteria, meaning they check the DO levels at one to two steps within the brewing process and there are efforts in place to maintain low DO levels.

In terms of purging oxygen from tanks within the brewing process, only **Wormtown** does so within all steps, earning them three out of three. **Twelve Guns**, **The Guild**, and **Wachusett** all purge oxygen only at one or two steps within the process and are not as worried about oxygen in the headspace of tanks.

There are two main ways the fill level and package quality are tracked, using an x-ray or a by weight. **Wormtown**, **Wachusett**, and **The Guild** all utilize either x-ray or a combination of x-ray and weight to track fill level, earning them a three in that criterion. Twelve Guns only uses a weight system to ensure the proper fill level. All four breweries track the quality of the packaging and kick cans off the packaging line if the can is compromised or the seam is not set. This is important to ensure that damaged or compromised products are not sold to distributors or the public.

Low Quality Practice Rankings

Bay State Brewing, **Redemption Rock Brewing**, and **Pivotal Brewing Co** all ranked in the bottom three, scoring less than twenty out of twenty-seven. The quality practices at these three could use significant improvement in multiple areas and in some cases, quality is not a priority of the brewery.

None of the three have quality labs and very minimal quality equipment. Shelf-life is only tracked by the carbonation levels and taste of the tap lines in the brewery and packaged cans or bottles are not stored on site and tested regularly. All three only scored one out of three in terms of spoilers and bacteria testing due to the inconsistent and irregular nature of testing. **Redemption Rock** and **Bay State** only take samples on a random basis, sometimes with many batches in between tests. **Pivotal** does testing on a semi-regular basis, ensuring that testing is done after every few batches.

As mentioned previously, all breweries source hops from the Pacific Northwest, which means quality is entrusted to the farmers and their supply chain, leading to the three remaining breweries to score a two out of three. **Pivotal** scored a two out of three on water quality and modification, strictly because of the higher quality of Bristol, RI city water than Worcester, MA water. **Redemption Rock** and **Bay State** both used Worcester water straight out of the tap, earning them a one out of three.

All three breweries utilized a carbonation stone to carbonate their beverages, earning them a two out of three in the carbonation technique criteria. **Redemption Rock** earned one out of three on DO tracking and maintenance because they only check DO levels on a random basis and at only one stage of the brewing process. **Pivotal** and **Bay State** both earned two out of three for monitoring DO levels at one or two steps of the brewing process on a consistent and regular basis. While **Pivotal** only tracks the DO levels at one of the stages in the process, the mobile canning company they use, called Iron Heart, monitors DO levels throughout the canning process. All three purged oxygen on a regular basis within their tanks, earning two out of three in that criterion. Finally, fill level was tracked by weight at **Pivotal**, **Redemption Rock**, and **Bay State Brewing**, which garnered a two out of three on the fill weight and package quality criteria. Overall, these three breweries had the lowest quality scores, due to their minimal emphasis on quality and limited quality practices.

Environmental Impact Findings

The second focal point of the craft brewing industry our group decided to highlight and rank after visiting each location was their Environmental Impact. This is a difficult aspect of the business to perfect because rules and regulations are different from town to town, meaning each brewery must abide by a different set of rules and regulations. As a result, this makes comparisons between locations somewhat of a challenge. Our team was still able to create a solid template to evaluate each brewery by dividing environmental Impact up into five main categories all with subsections. The criteria we developed are categorized generally based on the same questions we asked each brewery to avoid any possible discrepancies. The following is a discussion of these findings.

Environmental Impact Rankings – Top Performers

Out of the seven breweries, three met standards good enough to be credited with a rank of “high". Those three were **Twelve Guns Brewery, Isle Brewers Guild (or The Guild)**, and **Redemption Rock Brewing**. To achieve this distinction, a score of at least 25 out of 36 (approximately 70%) was required. These three breweries did an exceptional job in five selected aspects which are as follows: Raw Materials, Brewing Process, Packaging, Waste Management, and Water. When assessing the environmental Impact of raw materials, we evaluated how far the sourced material was coming from (in miles). The further away the distributor, the lower the score the brewery received. All three of the highlighted companies above received their raw materials from a local farmer within a 25-mile radius of their brewery. With the number of deliveries made annually between these two business partners a short venture is necessary to keep the environment clean. On a similar note, countless bags of all different materials get used and thrown away throughout these deliveries and the brewing process as a whole so having a reusable and or recyclable bag is very important. All three of these breweries used bags that were mostly if not completely made up of recyclable material. The third component of this first section was yeast usage. Yeast is essential to each batch of beer and can be deemed as the “secret ingredient” by some if they find a strain they really like and can harvest for generations. Some practices on the other hand did not see it as valuable and would not re-use the product much at all, therefore creating a lot more waste. **Twelve Guns Brewery** uses yeast for roughly 5-7 generations, **Redemption Rock** for 4-5, and **The Guild** for 8 or even more in some cases, which are all phenomenal.

When grading the brewing process for each company regarding environmental Impact, the two main categories were Overall Recycling Practices, and Carbon Dioxide (CO2) usage. The top three breweries all track and encourage recycling to the best of their abilities. The only reason they did not receive a maximum score here is because none of them owned a capture and condensate system. This is an expensive piece of equipment and for smaller to medium-scale breweries this is not in the budget. That can almost be considered a luxury for the recycling process, but they still do everything needed to ensure good practice.

CO2 usage is where **Twelve Guns** and **The Guild** received their lowest scores of the section while **Redemption Rock** had a perfect score. The reason they did not score higher was because they did not use any alternative to CO2 during the process and or attempt to trap or limit its quantity. Another reason that is not possible for them yet is because it also requires very expensive

equipment which requires both physical space and capital. **Redemption Rock** placed at the very top of this category, in fact no other breweries scored a perfect rank in this subsection besides them since they use 100% alternatives such as Nitrogen or natural gasses in their brewing process and eliminated the use of carbon dioxide.

The third of the five main sections assess the packaging's Impact on the environment, especially how much volume each brewery goes through annually. The two subsections evaluated were sustainable packaging, and packaging recycling. Both **Twelve Guns** and **Redemption Rock** had perfect scores, meaning that *all* their packaging is biodegradable, and it is easily recyclable/can be reused. **The Guild** scored less because even though their packaging was completely recyclable, it only was in certain areas, and it was not biodegradable like the others.

Waste Management comprises Spent Grain Disposal, City Dumping Requirements, and Chemical Usage. If the brewery does not properly take care of their waste, they can be fined as much as monthly with even harsher repercussions over time. On top of that, the environment is being negatively affected as well as the community around them and most of these locations are in well-populated cities or areas which could hurt the people around them if it is in a large enough recurring volume. **Twelve Guns** scored a perfect score in all three of the subsections previously mentioned. They send their grain to a farm within 25 miles of them to ensure low carbon emissions, follow the city requirements perfectly while also disposing of their waste ethically, and all the chemicals used in cleaning/sanitation are unharmful to the environment and care is taken to ensure that none of them are rid of in wastewater disposal. **The Guild** and **Redemption Rock** scored the same for all three minor sections which were on tier below **Twelve Guns**. As for the chemicals used during the process, they are not harmful to the environment and care is taken to offset their harm when disposed of.

Finally, the last and most important section is Water. We agreed on this as a team because beer is composed mainly of water so tracking the inflow/outflow of water along with its recapturing/reusing processes both contributing factors Impacting the process and daily operation. **Twelve Guns** and **The Guild** both scored the same in the tracking of inflow and outflow of water while **Redemption Rock** scored a tier below. As for the first two breweries mentioned, they track everything going in and out, which is important, but they do not ensure that the water is being utilized and not being wasted. This is also harder to come by with smaller scale breweries with not

enough staff or ways to track that end location of the water. **Redemption Rock** scored lower since they have no procedure in place to track the flow of water but can calculate it when needed, which is not done on a regular basis. Regarding the final subsection of recapturing/reusing they all scored very well. **Twelve Guns** recaptures both water and steam and uses it for the boiling and cleaning processes, while the remaining two breweries only recapture and reuse the water for the same processes.

Overall, these three breweries scored well compared to the others and their scores prove it. On a different note, there were certainly middle of the pack companies that teetered around the 25 range but unfortunately fell into the low category while others have room for some improvement.

Environmental Impact Rankings – Bottom Performers

Now that each section and their sub section has been completed, it is crucial to see where the remaining four breweries lost some of their points which caused them to score below a 25. When identifying some of the low scoring breweries for the environmental Impact section such as **Wormtown Brewing**, **Baystate Brewing**, **Wachusett Brewing Company**, and **Pivotal Brewing**, they all scored exceptional in other aspects of the ranking process but got edged out on a few specific areas for this section.

Starting with **Wormtown Brewing**, they scored a 22 out of 36 leaving them right on the cusp of 25 so they were not far off. We identified two areas where they could improve their score, and these were also areas where they scored less than some of the top three companies. The first was sustainable packaging. Only parts of their packaging can be recycled which was the only factor that saved them from logging a zero in this section. Some of the other larger breweries were able to score higher here so size should not be a huge factor. As a result, they have more waste than others, therefore dropping their sustainability rank. Secondly, we noticed that they scored low on the inflow outflow subsection of water. This means water inflow and outflow can be calculated and is on a non-regular basis to ensure water loss is not occurring, but not given a high priority. Since they operate at such a large scale this would take a lot of time and equipment expense, which does not really improve quality dramatically, but in the future, it would be nice to have. We decided to highlight these two and will continue to do so for the remaining breweries because we feel these

areas could be improved quickly and easily by these companies and as a result lead to improvement in importing their score and environmental Impact.

Pivotal Brewing is the next company who also scored a 22 out of 36. The first thing that stood out to our group regarding this location was that they do not often reuse their yeast and dumped it after just a few generations. Most companies take pride in their yeast and the flavor it gives so we felt this was surprising. They do not use any contract brewing so they only must make sure they hit their standards, but a trademark flavor comes with a trademark yeast. This is a new brewery so as they continue to establish themselves and expand, hopefully yeast starts to be used longer which would lead to a jump in their score. The other area we noticed here was packaging and recycling options. Their score here was low because their packaging can only be recycled at the brewery. Like many others, PakTech plastic beer holders are used, which cannot be broken down. **Pivotal** does provide a service where if you bring that holder back to them, they clean it and reuse them, which is great but just not convenient or at a 100% success rate.

The final brewery is **Baystate Brewing**. They scored a 20 in this section, but with a few changes could be right near that 25-point range. The first one is the sourcing of raw materials. They source from somewhere within a 150-mile radius. No other brewery had to go that far for a quality farm which is why they lost points. Regarding the packaging, their scores were fairly low as well. They used plastic tops which contributed to both low scores in this subsection. This is not an easy fix because the non-plastic biodegradable tops are expensive, but we believe there are ways to slightly improve this section.

Economic Sustainability Findings

Economic sustainability was the last of the three main criteria categories listed in our methodology. The most apparent outcome from this criterion was able to see how different breweries varied in their methods to sustain their business financially sustain their business. Throughout visits, the team was able to pick up some great ideas from breweries, as well as find out which breweries could be doing a bit more to help bring in larger crowds and earn more revenue. Below will be some of the methods from the highest and lowest ranking breweries in our criteria. The best scorer in the economic sustainability criteria was **Wormtown** with a very impressive 18 out of 21 points.

Economic Sustainability Rankings – Top Performers

This section will be evaluating breweries with the top scoring advertising, tap rooms, contracts/partnerships, can designs, merchandise, distribution, and adaptability to new markets. It is important to remember that some breweries do operate on a much larger scale and have more funds/revenue. In terms of social media presence, the best brewery was **Wormtown Brewing** with major presences on Instagram, Twitter, and Facebook. They also advertise fun-themed nights such as trivia nights to help bring in a larger crowd. The accounts are extremely active and some of the highlights are advertisements of new or seasonal beers and drinks. Their social media team reaches out to a fun and outgoing crowd of all ages, creating an environment for everyone.

For taprooms, there were some very impressive and rustic looks, as well as some plans for expansion. The first notable tap room is **Redemption Rock.** For one of the smallest breweries, they have one of the most impressive tap rooms. The room encourages a social setting by having a massive wall filled with board games for anyone to use at any time. There are also plenty of active games to play on the turf section of their tap room with games such as corn hole and massive renditions of Jenga and Connect Four. **Redemption Rock** also has a massive screen with a projector for events such as movie or trivia nights which draw in larger crowds. **Redemption Rock** also brews their own coffees and teas, helping the brewery have a coffee shop type feel in the early hours. To go along with the coffee shop, the brewery also produces their own delicious pretzels and other delicious food offerings. Lastly, the brewery encourages dogs, which seems to be a consistent norm in the brewing industry. **Twelve Guns Brewing** who has a plan for expansion. The brewery is currently building a full-scale restaurant/taproom that will include a giant screen, stage, golf simulator, and bowling alley lanes, likely making it a top spot in Rhode Island for all beer lovers.

A major part in a brewery expanding is gaining contracts and partnerships with other breweries to fill any unused capacity. **The Guild** is a contract brewery that also produces their own beer. Within a year's time, they will contract with well over ten breweries and brew anywhere from one to fifteen styles of beers/seltzers for that brewery. **Wormtown** and **Wachusett** also do a phenomenal job contracting and producing more beer than any of the other breweries. **Bay State** also deserved some recognition because of their wholesale as well. They have over fifteen different varieties and liquor stores that they wholesale too, they also do a great job showing this on their website.

In terms of can designs, one brewery absolutely stood out above the rest. **Twelve Guns** hired a talented and creative artist to help with their can designs. These cans are designed to catch the eye of a consumer. Pictured below are some of the team's favorite designs that really speak for themselves in Figure 7. Other breweries with great designs were **Wormtown**, **Pivotal**, and **Wachusett**.

Figure 8: Twelve Guns Brewing Can Designs (Twelve Guns Brewing, 2022)

For merchandise, there were three breweries that seemed to stand above the rest, **Wachusett**, **Wormtown**, and **Redemption Rock** all have a huge variety of merchandise that is desirable, stylish, and practical for the average brewery consumer. **Wachusett's** eye-catching, can shaped glass, **Wormtown's** "Be Hoppy" shirts, and **Redemption Rock's** stylish coffee mugs to go along with their coffee and tea brewing are notable examples.

Figure 9: Wormtown "Be Hoppy" Shirt

Distribution is an important part of a successful brewery, and some breweries are doing well and do not see benefits in expanding distribution. An example of this was **Pivotal Brewing**, a relatively new brewery in Rhode Island that has great beer to keep in house and has no need for distribution since customers just keep coming back for it. The most impressive distribution service was from **Twelve Guns. F**or a relatively small-scale brewery, their distribution strategy is impressive with Twelve Guns establishing their own distribution service. The owner had concerns with their prior distribution service during COVID-19 and decided to drop that service altogether and start his own. Larger scale breweries such as **Wormtown**, **Wachusett**, and **The Guild** have effective methods of distribution and do very well.

Almost every brewery that we visited had an alternative to beer as another revenue stream. The most interesting one was from Pivotal who brewed their own non-alcoholic root beer, and the owners saw immediate success from the product. The most notable seltzer was the Cannon & Anchor brand from **Twelve Guns. Wormtown** showed commitment to perfecting RTDs (Ready to Drink Cocktails) in their quality lab. Their Mai Tai was still under testing but held up as one of the best non-beer drinks that we tasted. **Redemption Rock** has an incredible array of options varying from in-house peppermint mocha espresso to apricot mango and ginger lime kombucha

flavors, and everything in between. **Bay State** also puts forward their very successful Bling Seltzer as an alternative for beer drinkers.

Economic Sustainability Rankings – Bottom Performers

Before discussing some of the lower rankings of economic sustainability, it is important to note that the breweries being evaluated were among some of the best in the Northeast of the United States, a low score in something such as social media or merchandise absolutely does not discredit the effort and hard work of each brewery. None of these breweries were perfect. In terms of social media, every brewery does have a platform where they are able to advertise their themed nights and/or new deals and drinks, but many could benefit from improved efforts. Merchandise can be a big help for most smaller breweries. **Twelve Guns** had some great merchandise, especially with some of their incredible can designs on merchandise, but it seems like they could be doing more. For example, a glass with their can designs on them or even a coaster using those same designs would likely sell just as well as their clothing. **Pivotal** is very similar and they only sell shirts and sweatshirts, but they also have wonderful designs and could diversify their merchandise.

Contract brewing can is a great way to get a specific beer or name out for more beer drinkers to see, however that is not the goal for all breweries. Breweries like **Pivotal** and **Redemption Rock** chose not to partner with contractor breweries and produce more beer than they can produce in-house. They both have very strong regular customers which means that their beer is good enough to find a partner, but they seem to choose to focus on their in-house production.

Adaptability to new markets is vital for any business in any industry, creating a new product to attract new customers can be the difference between a good business and a great business. **Pivotal** was the only brewery we visited that did not have any alcoholic alternatives to beer, however they do have a non-alcoholic root beer. Not everyone is a beer fan and an argument can be made that non beer fans would not be looking to go to a brewery anyway, however if you do make a successful seltzer or ready-to-drink-cocktail it could bring an entire new audience to your brewery.

Taprooms are what make a brewery feel like a brewery. Every business has their own vision of what they want their taproom to be. If you prefer a rustic, industrial type feel then **The Guild** and **Pivotal** are perfect options. If you feel more inclined to be in a social setting, then a brewery like **Redemption Rock** or **Twelve Guns'** new building would be ideal.

Quality Recommendations

While **Twelve Guns Brewing** ranked highest out of the small craft breweries that were visited, there are a few recommendations our team compiled for **Twelve Guns.** The first and most important recommendation is to implement a quality lab within the brewery. **Twelve Guns** plans to do this within their expansion, but this is a crucial element of high-quality practices. Including forced fermentation machines within the lab, this is recommended to understand the exact timeline needed for yeast fermentation. This will also let brewers know if there are any issues within the fermentation process, they need to be aware of before fermentation starts. Also, within the quality lab, we recommend implementing testing for spoilers and bacteria, which would require a fume hood and laboratory-grade testing equipment and tools. Finally, having adequate storage space within the quality lab for shelf-life testing batches is important to ensure that all batches are kept in the exact same conditions and outside variables aren't affecting the shelf life. Within shelf-life testing, it is also recommended to have multiple taste testers who utilize a digital application to track all feedback. Having multiple testers is important to ensure that there is no bias or anomaly within one tester. Our team also recommends utilizing an x-ray machine to check fill level instead of weight. This helps to identify if any foreign objects made their way into the cans somehow and is more accurate than using a scale. The last quality recommendation for **Twelve Guns Brewing** is to check DO levels at every step within the brewing process, not only at the two steps they check at.

These recommendations should be taken into consideration when upscaling. At the new larger location all these changes are realizable in the larger space and with the increased production.

Environmental Impact Recommendations

Environmentally speaking, **Twelve Guns** scored at the top of the pack, but there were two areas our team targeted as room to improve, especially with their expansion underway. When looking at the brewery rankings, there was an evaluation conducted for the current Twelve Guns location and one completed for the future location. CO_2 usage was an area we saw fit for improvement, and the reason our team identified this first recommendation area is because it ranked the same in both the current and future location at its lowest score (1 out of 3). After the expansion is finalized and put into place with new and improved equipment, there is a possible window to implement a new

system to help limit the CO_2 usage during the brewing process and potentially seek an alternative in a certain aspect of the process. Our team understands this is easier said than done, but not many breweries in this study were able to accomplish this. In fact, out of every location we visited, only two scored above a 1 on our CO_2 usage criteria. Finding out a way to limit its usage and using a substitute for certain processes, if possible, would create diversity between 12 Guns and their competitors while also taking some stress of acquiring CO_2 if it becomes scarce again in the future.

The second area for improvement is regarding yeast. Twelve Guns already does well in this area, but once again with the company growing, this could prove to be a crucial challenge. After meeting with many breweries, the most successful ones preach using their yeast for as many generations as possible. Some even refer to yeast as their "secret recipe" once they find a flavor that tastes better than previous generations. Our team understands that Twelve Guns uses their yeast for approximately 5-7 generations which is a strong start, however with an increase in yearly barrel production with the new location, using yeast for many generations to preserve that same taste and limit overall waste is more important than ever.

One last recommendation is something our team deemed important because of the upcoming expansion. Proper raw material packaging is crucial. As orders will be coming in with more volume and frequency to meet growing demand, more waste and an overall buildup of trash will occur. Currently, most raw materials are packaged in mesh-like recyclable bags which is great, but if possible, making the change to completely reusable or recyclable raw material packaging will reduce the overall carbon footprint non "green" packaging creates.

Most of these recommendations are costly and are not simple changes, but with a growing company and great creative minds working around the clock, we see some of these as feasible changes for the future that could greatly benefit the overall environmental score of the future Twelve Guns.

Economic Sustainability Recommendations

In terms of economic sustainability, every business has different plans and methods to keep a constant flow of income, however from our studies, these are a few recommendations that could help Twelve Guns gain more revenue. The first is to obviously get the newly planned taproom open as soon as possible, as that taproom is ideal for gaining income and has many ways for

customers to spend money. Twelve Guns should also put more investment into their merchandise. This could include offering new products and clothing in addition to their current offerings. Their can designs are known to be one of the best by locals, so the team recommends using these designs on the merchandise as well as on the cans.

Social media is a large part of any promotional plan, and while Twelve Guns' presence on social media platforms is strong, hiring a full-time social media manager could help them be more effective and efficient when promoting the brand.

Conclusion

From the outset of this project, our team sought to learn more about the brewing industry, their brewing practices, and the missions of different breweries. The largest takeaway we found is that the common belief that the brewing industry has a negative impact on the environment is a myth. There are many brewers who strive to create the highest quality products with the least impact on the environment. They are accomplishing this in many ways and more and more brewers are learning about these practices. The goal of this project was to understand the current Quality, Environmental Impact, and Economic Sustainability practices of craft brewers throughout Massachusetts and Rhode Island to assist Twelve Guns Brewing as they plan to scale up their business in the coming year. By visiting seven different breweries and compiling all data that was collected, our team created a comprehensive set of recommendations for Twelve Guns during their expansion, along with recommendations for the other six brewers on how to improve their current process. Appendix C consists of the deliverable that our team handed over to Twelve Guns Brewing and the other breweries visited after the completion of this project.

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Appendix A. Brewery Questions

Appendix A.1 Quality Questions

Category	Question
Raw Materials	Where are raw materials sourced from?
	Is city water or well water used?
	Is water used as is from the source or modified?
Brewing Process Sustainability	How are beverages carbonated?
	Are Dissolved Oxygen (DO) levels tracked and if so how?
	At what steps in the process is DO measured?
	How are DO levels maintained?
	Is headspace purged in bright tanks?
Packaging	Is the fill level measured in the canning process?
	Are cans purged to get rid of DO before being filled?
	Are cans x-rayed for foreign objects?
Quality Lab	Is there a quality lab within the brewery?
	What equipment and tools are used in the quality lab?
	Is shelf life tracked? If so, how?
	Are tanks tested for spoilers and bacteria?

Appendix A.2 Environmental Impact Questions

Category	Question
Raw Materials	Are raw materials sourced locally and from sustainable sources?
	Is inflow & outflow of water tracked?
	Are raw materials shipped in sustainable packaging that can be reused or recycled?
	Is yeast used for multiple generations before being dumped?
Brewing Process Sustainability	Are used boxes, plastic wrap, etc recycled or reused?
	Is Nitrogen or CO2 used?
	Is steam recaptured and condensed into usable water?
Packaging	Is sustainable packaging used?
	Is there a recycling program for packaging?
Waste Management	Is spent grain given to a local farm?
	Are city dumping requirements followed?
	Are environmentally friendly chemicals used?
	Is waste neutralized to be less harsh?

Appendix B. Criteria Description & Reasoning

Appendix B.1 Quality Criteria Description and Reasoning

Criteria		Rank	Reasoning
Quality Lab	Quality Lab	0	No quality lab at all
		1	Minimal quality equipment, no physical room for quality
		2	Quality room established with equipment; testing done regularly
		3	Exceptional quality lab and equipment, testing and experimenting done (including new flavors/products, new boiling techniques, etc)
	Shelf-Life Testing	0	No shelf-life testing is done
		1	Shelf-life testing completed on an irregular basis, only taste testing, no application/digital record keeping used
		2	Shelf-life testing done on a regular basis but not every batch tested, records are kept digitally, usually only one taste tester
		3	Shelf-life testing is done on every batch brewed, digital record keeping utilized, multiple taste-testers
	Test for Bacteria/ Spoilers	0	Equipment and cans/bottles not tested for any spoilers or bacteria
		1	Minimal equipment is tested for spoilers or bacteria
		2	Equipment and cans/bottles are tested for spoilers or bacteria on a semi-regular basis
		3	Equipment and cans/bottles are regularly tested for spoilers or bacteria with high grade testing
Raw Material Quality	Sourcing of Raw Materials	0	No tracking of raw material quality, sourcing is not a major concern
		1	Raw material source is tracked, but steps are not taken to ensure highest quality
		2	Raw material source is tracked, care is taken to understand the company's process and quality
		3	Steps are taken to ensure highest quality of raw materials is sourced, above and beyond care taken
	Sourcing of Water & Modification	0	Water quality is not a concern, not tracked or monitored
		1	Water quality is understood and maintained; no effort taken to ensure highest quality is achieved

		2	Brewery ensures high quality of water is used, quality is tracked consistently, and steps are taken to prevent low quality water being used
		3	Brewers go above and beyond to ensure the highest quality of water possible is utilized, complex techniques such as reverse osmosis are utilized to develop high quality water formulas
Process Quality	**Carbonation Technique**	0	Technique of carbonation is not tracked to ensure high quality carbonation
		1	Common technique such as carbonation stone used, but carbonation levels and timing is not tracked closely
		2	Carbonation stone or other higher quality technique such as ___ used to track carbonation levels consistently and ensure proteins are not disturbed
		3	High quality carbonation technique is used to ensure carbonation is consistent at the desired rate and the brew is not disturbed
	DO Level Tracking & Maintenance	0	DO levels are not tracked throughout the brewing process and there are no practices in place to maintain a low DO level
		1	DO levels are not tracked throughout the brewing process, but there are practices in place to ensure that the DO level is kept relatively low
		2	DO levels are tracked at 1-2 steps throughout the brewing process, and there are practices in place to ensure DO level is kept to a desired level
		3	DO levels are tracked at every stage within the brewing process, and practices are in place to ensure DO levels are kept to a very minimum (such as bubble breaking, purging, etc)
	Purging of Oxygen	0	Oxygen is not purged at any stage within the brewing process
		1	Oxygen is purged from the headspaces within brite tanks on a semi-regular basis, but not in any other process of the brewing
		2	Oxygen is purged from the headspaces within brite tanks on a regular basis (daily) and cans/bottles are purged before being filled
		3	All possible areas of the brewing process are purged of oxygen in between each batch creation, including the brite tanks, cans/bottles, etc
Packaging Quality	**Tracking of Fill Level & Package Quality**	0	Fill Level is not tracked throughout the packaging process and quality of the package is not tracked
		1	Fill level is tracked semi-regularly using a weight system and removed from the line if not up to desired level, and if package is compromised (can opened, hole, etc) line will remove it
		2	Fill level is tracked throughout the canning process using an x-ray system and if packaging is compromised the line will remove it
		3	Fill level is tracked throughout the canning process using multiple forms of equipment such as weight and x-ray, and if packaging is compromised the line will remove it

Appendix B.2 Environmental Impact Criteria & Reasoning

Criteria		Rank	Reasoning
Raw Materials	Sourcing of Raw Materials	0	Materials are sourced from outside a 150 mile radius
		1	Materials are sourced from a local (Within 150 miles) farm/farmer
		2	Materials are sourced from a local (Within 75 miles) farm/farmer
		3	Materials are sourced from a local (Within 25 miles) farm/farmer
	Raw Material Packaging	0	Materials are packaged in wasteful plastic
		1	Some materials are packaged in reusable or recyclable materials such as a mesh-like bag
		2	Most materials are packaged in reusable or recyclable materials such as a mesh-like bag
		3	All materials are packaged in reusable or recyclable materials such as a mesh-like bag
	Yeast Usage	0	Yeast is not reused and often disposed of after very few generations are used - not sustainable
		1	Yeast is reused for a few generations, roughly 2-4, then disposed of
		2	Yeast is reused for multiple generations, roughly 5-7, to ensure sustainability and cut down on total amount of raw materials needed
		3	Yeast is kept and reused for many generations, around 8 or more, for maximum sustainability and keeping raw material usage and shipping at a minimum
Brewing Process	Recycling Practices	0	Recycling is not tracked or cared for
		1	Recycling is tracked, but no sign of encouragement
		2	Recycling is tracked and encouraged
		3	Condensate and Capture system is owned, recycling is tracked and encourage
	CO2 Usage	0	CO2 usage not tracked and utilized in all areas of the brewing process such as oxygen purging and in the taproom
		1	Company tracks CO2 usage and utilizes it in all areas of the brewing process
		2	Company tracks and tries to limit CO2 usage, with Nitrogen or other natural gases used in some steps of the brewing process
		3	Company uses no CO2, and utilizes an alternative instead such as Nitrogen or other natural gases
Packaging		0	Packaging cannot be recycled

	Sustainable Packaging	1	Packaging can partly be recycled
		2	Packaging is completely recyclable
		3	Packaging is completely biodegradable
	Packaging Recycling	0	Packaging cannot be recycled
		1	Packaging can only be recycled at brewery
		2	Packaging can only be recycled in certain areas
		3	Packaging is easily recycled, reusable, or biodegradable
Waste Management	**Spent Grain Disposal**	0	Grain is seen as waste and not repurposed or reused in any way
		1	Grain is sent to a local farm within a 150-mile radius with little regard for carbon emissions or composted
		2	Grain is sent to a local farm within a 75-mile radius to try to keep carbon emissions relatively low
		3	Grain is sent to a local farm within a 25-mile radius to ensure carbon emissions are at a minimum
	City Dumping Requirements	0	City requirements are not met, and waste is disposed of unethically
		1	City requirements are not met but waste is disposed of ethically
		2	City requirements are mostly followed, and waste is disposed in an ethical way
		3	City requirements are followed perfectly, and waste is disposed in an ethical way
	Chemical Usage	0	Chemicals used in cleaning and sanitation are very harmful and all are disposed of with other waste in an unsustainable way
		1	Chemicals used in cleaning and sanitation are somewhat harmful to the environment and often disposed of with minimal care to their environmental impact
		2	Chemicals used in cleaning and sanitation are mainly not harmful to the environment and care is taken to offset their harm when they are disposed of
		3	All chemicals used in cleaning and sanitation are unharmful to the environment and care is taken to ensure that none are disposed of in wastewater disposal
Water	**Inflow/ Outflow Tracking**	0	Water inflow and outflow is not tracked at all, no priority is given to calculating the amount of water used vs wasted
		1	Water inflow and outflow can be calculated and is on a non-regular basis to ensure water loss isn't occurring, but not given a high priority
		2	Water inflow and outflow is tracked; however, priority is not given to ensure that water is being utilized and not wasted
		3	Water inflow and outflow is tracked, priority given to ensure that water is being utilized and not wasted

	Recapturing/Reusing	0	There is no attempt to recapture water
		1	Water is recaptured but not reused
		2	Recaptured water is utilized in boiling and cleaning processes
		3	Recaptured water AND steam are utilized in boiling and cleaning processes

Appendix B.3 Economic Impact Criteria & Reasoning

Economic Sustainability			
Criteria		**Rank**	**Reasoning**
Marketing	**Social Media**	0	Company does not utilize social media
		1	Company has one platform being used well
		2	Company has 2 platforms being used well
		3	Company has a very apparent presence on all major platforms (IG, Twitter, FB) and interactions from customers
	Merchandise	0	Company does not sell merchandise
		1	Company sells clothes
		2	Company sells more than just clothes
		3	Company sells stylish, high demand clothing, glasses, hats, coasters, ect.)
	Artistic/ Unique Can Design	0	Arbitrary
		1	Arbitrary
		2	Arbitrary
		3	Arbitrary
Other	**Partnerships /Contract brewing**	0	Company does not have any brewing clients or partners that they contract brew for
		1	Company has 1 brewing client or partner that they contract brew for or who brews for them
		2	Company has 2 brewing clients or partners that they contract brew for or who brews for them
		3	Company has 3+ brewing clients or partners that they contract brew for or who brews for them
	Distribution	0	Location does not have a distribution service
		1	Location outsources their distribution service
		2	Location made a deal with a distributor to move their products
		3	Location owns their own distribution company
		0	Location produces only their beer

	Adaptability to new markets	1	Location offers 1 alternatives beer (Seltzers, RTDs, Limited edition brews, non-alcohol brews, alcoholic "sodas")
		2	Location offers 2 alternatives
		3	Location offers 3 or more alternatives
	Unique Offerings	0	Location does not have any amenities
		1	Location encourages social settings
		2	Location has some amenities and has a great social setting
		3	The location is filled with entertainment; themed nights, games, and a social setting

Appendix C. Individual Brewery Reports

WPI Craft Brewing Student Project Findings

Twelve Guns Brewing

Total Ranking:
63 out of 84
3rd overall
out of 7

Quality

18 out of 27

Pros: Raw material sourcing, Purging of Oxygen, Spoiler testing, Carbonation Technique

Cons: No on site quality lab, canning line small compared to output

Environmental Sustainability

30 out of 36

Pros: Raw materials all around, Recycling practices, Spent grain disposal, waste management

Cons: Complete tracking of inflow out flow, Utilization of nitrogen

Economic Sustainability

15 out of 21

Pros: Social media presence, can design,

Cons: Contract Brewing

Takeaways

- Quality is what they preach, but need an onsite lab
- Top scoring Environmental brewery
- Economically there was a lot of effort in every aspect

Recommendations

- Check DO at every step
- Potentially find a niche for Nitrogen
- Advertise merchandise more

Thank you so much for assisting us with this project and letting us visit your brewery!

WPI Craft Brewing Student Project Findings

Twelve Guns Brewing

Brewery Rankings	QUAL	ENV	ECON	SCORE
Wachusett Brewing	26	23	16	65
Wormtown Brewing	24	22	18	64
Twelve Guns	18	30	15	63
The Guild	22	26	14	62
Redemption Rock	15	25	15	55
Pivotal Brewing	16	22	9	47
Bay State Brewing	11	20	12	43

WPI Craft Brewing Student Project Findings

Wormtown Brewing

Total Ranking:
64 out of 84
2nd overall
out of 7

Quality

24 out of 27

Pros: DO tracking, X-ray fill tracking, Large quality lab, shelf-life tracking, forced fermentation
Cons: generations of yeast used

Environmental Sustainability

22 out of 36

Pros: Water reuse, Nitrogen usage, Polypro tops
Cons: dumping measures not tracked consistently, not easily recyclable packaging

Economic Sustainability

18 out of 21

Pros: strong social media presence, contract brewing, adaptability
Cons: can design art, diverse offerings

Thank you so much for assisting us with this project and letting us visit your brewery!

Takeaways

- Large focus on sustainability but could be improved
- Impressive quality lab
- Spoiler testing and shelf-life done frequently

Recommendations

- Look into cardboard packaging or offer customer incentive to bring back tops
- track inflow and outflow of water on regular basis

WPI Craft Brewing Student Project Findings

Wormtown Brewing

Brewery Rankings	QUAL	ENV	ECON	SCORE
Brewery D	26	23	16	65
Wormtown Brewing	24	22	18	64
Brewery A	18	30	15	63
Brewery F	22	26	14	62
Brewery C	15	25	15	55
Brewery E	16	22	9	47
Brewery B	11	20	12	43

WPI Craft Brewing Student Project Findings

Wachusett Brewing

Total Ranking:
65 out of 84
1st overall
out of 7

Quality

26 out of 27

Pros: outfitted quality lab, high-end shelf-life testing process
Cons: Tracking of DO levels could be improved

Environmental Sustainability

23 out of 36

Pros: Sustainable raw material sourcing
Cons: Minimal recycling options for packaging

Economic Sustainability

16 out of 21

Pros: Large social media presence and strong marketing
Cons: Minimal diverse offerings (different types of beverage)

Thank you so much for assisting us with this project and letting us visit your brewery!

Takeaways

- Quality was the most impressive we saw of all breweries evaluated.

Recommendations

- Looking into more environmentally efficient ways of packaging beers

WPI Craft Brewing Student Project Findings

Wachusett Brewing

Brewery Rankings	QUAL	ENV	ECON	SCORE
Wachusett Brewing	26	23	16	65
Brewery B	24	22	18	64
Brewery A	18	30	15	63
Brewery F	22	26	14	62
Brewery C	15	25	15	55
Brewery E	16	22	9	47
Brewery B	11	20	12	43

WPI Craft Brewing Student Project Findings

Bay State Brewing

Total Ranking:
43 out of 84
7th overall
out of 7

Quality

12 out of 27

Pros: Source high quality raw materials, consistent carbonation technique and tracking of DO levels
Cons: minimal bacteria & spoilers testing and shelf-life testing

Environmental Sustainability

20 out of 36

Pros: recyclable raw material packaging, spent grain disposal and reuse
Cons: non-sustainable packaging, no recapture/reuse of water for cleaning/cooling

Economic Sustainability

12 out of 21

Pros: diverse offerings onsite, adaptability to new markets
Cons: minimal social media presence

Thank you so much for assisting us with this project and letting us visit your brewery!

Takeaways

- Taproom environment is strong and great food and drink offerings on tap
- DO levels are tracked at crucial points

Recommendations

- focus more on recycling and environmental sustainability
- look into packaging alternative
- improve social media presence

WPI Craft Brewing Student Project Findings

Bay State Brewing

Brewery Rankings	QUAL	ENV	ECON	SCORE
Brewery D	26	23	16	65
Brewery B	24	22	18	64
Brewery A	18	30	15	63
Brewery F	22	26	14	62
Brewery C	15	25	15	55
Brewery E	16	22	9	47
Bay State Brewing	11	20	12	43

WPI Craft Brewing Student Project Findings

Redemption Rock Brewing Co.

Total Ranking:
55 out of 84
5th overall
out of 7

Quality

15 out of 27

Pros: High quality suppliers, purging of headspace, quality shelf-life tracking procedure including pH and gravity
Cons: no quality lab, minimal tracking of DO levels

Environmental Sustainability

25 out of 36

Pros: Less harmful chemicals for cleaning, dilute spent water, E6PR packaging used, Nitrogen
Cons: not tracking inflow/ outflow of water, looser city dumping requirements to follow

Economic Sustainability

15 out of 21

Pros: diverse & unique offerings, strong social media presence, utilize mobile canning company
Cons: not as strong adaptability to new markets

Thank you so much for assisting us with this project and letting us visit your brewery!

Takeaways

- Really strong in terms of sustainability - especially w/ cardboard packaging
- Wonderful taproom experience and offerings
- High quality for small operation and space

Recommendations

- Implement a quality room - utilize leased equipment from Iron Heart
- Track DO levels and inflow / outflow of water consistently

WPI Craft Brewing Student Project Findings

Redemption Rock Brewing Co.

Brewery Rankings	QUAL	ENV	ECON	SCORE
Brewery D	26	23	16	65
Brewery C	24	22	18	64
Brewery A	18	30	15	63
Brewery F	22	26	14	62
Redemption Rock	15	25	15	55
Brewery E	16	22	9	47
Brewery B	11	20	12	43

WPI Craft Brewing Student Project Findings

Pivotal Brewing

Total Ranking:
47 out of 84
6th overall
out of 7

Quality

16 out of 27

Pros: Iron Heart provides great quality service
Cons: More efficient testing for bacteria and spoilers could save a lot of beer in the long run

Environmental Sustainability

22 out of 36

Pros: Pak-tech recycling program
Cons: Minimal yeast reusal

Economic Sustainability

9 out of 21

Pros: Tap room and can designs are aesthetic and eye-catching
Cons: Distribution and contracts with other breweries

Takeaways

- The smallest brewery we visited but was able to hold ground with some of the larger enterprises, very impressive.

Recommendations

- Distribution is always a great way to find new, non-local consumers.

Thank you so much for assisting us with this project and letting us visit your brewery!

WPI Craft Brewing Student Project Findings

Pivotal Brewing

Brewery Rankings	QUAL	ENV	ECON	SCORE
Brewery D	26	23	16	65
Brewery E	24	22	18	64
Brewery A	18	30	15	63
Brewery F	22	26	14	62
Brewery C	15	25	15	55
Pivotal Brewing	16	22	9	47
Brewery B	11	20	12	43

WPI Craft Brewing Student Project Findings

The Guild Brewing

Total Ranking:
62 out of 84
4th overall
out of 7

Quality

22 out of 27

Pros: Quality Lab & Testing, Fill level and package quality, Raw materials sourcing
Cons: Tracking of DO, purging oxygen

Environmental Sustainability

26 out of 36

Pros: Raw materials overall, tracking and reusing of water, packaging options
Cons: Nitrogen utilized, waste management

Economic Sustainability

14 out of 21

Pros: Merchandise, Contract brewing, unique offerings
Cons: Distribution company, adaptability, can design

Thank you so much for assisting us with this project and letting us visit your brewery!

Takeaways

- Exceptional quality lab, and also largest contract brewer we visited
- Great when using raw materials
- Need a solid distributor

Recommendations

- Market further outside NE to contract brew for
- More in-house product
- More of social media presence

WPI Craft Brewing Student Project Findings

The Guild Brewing

Brewery Rankings	QUAL	ENV	ECON	SCORE
Brewery D	26	23	16	65
Brewery F	24	22	18	64
Brewery A	18	30	15	63
The Guild	22	26	14	62
Brewery C	15	25	15	55
Brewery E	16	22	9	47
Brewery B	11	20	12	43