Project Proposal Feasibility Study

Team 3: iBrew

Alissa Jones, Lota Onwumelu, Nolan Worstell

Engr 339/340 Senior Design Project

Calvin College

12 November 2012
Executive Summary

Team iBrew of Calvin College’s 2013 senior class of engineers will design a microbrewery with a carbon dioxide compression and purification system. The design is profitable at $8 million annualized income for a 3 year period. The proposal was made to the college by local brewer and alum, Barry VanDyke of Harmony Brewery, who wanted to reduce the overall carbon dioxide used by his brewery. Because there is little data available concerning off-gas composition of fermentation tanks, the team assembled an analytical pipe to measure gasses from Harmony’s tanks to model the carbon dioxide production rate along with impurity concentration over time. The feasibility of a compression and purification system for Harmony depends upon the initial purity of the gasses and space and economic constraints. A hypothetical microbrewery will be designed using Super Pro Designer software to evaluate the economies of scale of the batch system from a theoretical basis rather than industry experience.
# Table of Contents

1 Introduction ........................................................................................................................................ 8

2 Project Management .......................................................................................................................... 8
   2.1 Method of Approach ...................................................................................................................... 8
   2.2 Team Organization ....................................................................................................................... 10
   2.3 Schedule ..................................................................................................................................... 10
   2.4 Budget ......................................................................................................................................... 11

3 Requirements .................................................................................................................................... 12

4 Design Norms .................................................................................................................................. 12
   4.1 Cultural Appropriateness ............................................................................................................. 12
   4.2 Transparency ............................................................................................................................... 12
   4.3 Integrity/Trust ............................................................................................................................... 12
   4.4 Stewardship ............................................................................................................................... 13

5 Overall Brewery ............................................................................................................................... 13
   5.1 Mash Tun ..................................................................................................................................... 15
      5.1.1 Heat exchanger ..................................................................................................................... 15
      5.1.2 Filter ..................................................................................................................................... 15
   5.2 Wort Kettle .................................................................................................................................. 16
      5.2.1 Heat exchanger ..................................................................................................................... 16
      5.2.2 Filter ..................................................................................................................................... 16
   5.3 Fermentation Tank ........................................................................................................................ 16
   5.4 Beer Conditioning ....................................................................................................................... 18
   5.5 Beer Filtration .............................................................................................................................. 18
   5.6 Beer Carbonation .......................................................................................................................... 18
      5.6.1 Traditional methods ............................................................................................................. 18
      5.6.2 CO2 Capture and Compression System .................................................................................. 18
   5.7 Bottling Process ............................................................................................................................. 19

6 Task Specifications and Schedule .................................................................................................... 20

7 Experiment ....................................................................................................................................... 21
   7.1 Design Method ............................................................................................................................. 21
   7.2 Design Alternatives ...................................................................................................................... 21
# Table of Figures

Figure 1: Overall Brewery PFD ................................................................. 14
Figure 2: Purification and Recycle Diagram .......................................................... 19
Figure 3: GC/MS output for Air and Gas Sample, full Spectrum ........................................... 23
Figure 4: GC/MS output for Air and Gas Sample, Low count focus ............................................. 24
# Table of Tables

Table 1: Table showing major tasks ........................................................................................................... 20  
Table 2: Table showing rating scale for major tasks........................................................................................ 20  
Table 3: Materials of Construction Design Matrix .......................................................................................... 21  
Table 4: Velocity Measurement Design Matrix .............................................................................................. 22  
Table 5: Growth of Craft Breweries Industry .................................................................................................. 27  
Table 6: Pricing per Volume of Product ......................................................................................................... 29  
Table 7: Gross Profit Margin during scale-up .................................................................................................. 29  
Table 8: Balance Sheet ..................................................................................................................................... 31  
Table 9: Equipment Estimate Costs ............................................................................................................... 32
1 Introduction

Barry Van Dyke approached Calvin College in the summer of 2012 with the idea of making his small brewpub more environmentally friendly. The way that Barry proposed to do this was by the implementation of a CO\textsubscript{2} capture and compression system. Barry got the idea by looking his brewery and considering how he vented CO\textsubscript{2} from his fermentation tanks and then turned around to buy more CO\textsubscript{2} from a vendor and realized that he must be releasing a significant amount of CO\textsubscript{2}. With this knowledge in mind, Barry decided that his brewery needed to change how it operated to reduce the impact the brewery was having on the environment.

Later in the summer, Calvin College posted options for senior design projects and the forming Team iBrew expressed interest. With the start of the school year, Team iBrew officially accepted Barry’s project as their senior design project. Shortly after team iBrew accepted Barry’s project, the team advisor, Wayne Wentzheimer, suggested that the team should look beyond just producing a one off project of a CO\textsubscript{2} capture and compression system to designing a full-fledged microbrewery so that the design of the CO\textsubscript{2} system could be incorporated into future sustainable microbreweries and serve as an example for how existing breweries can be retrofitted to incorporate a CO\textsubscript{2} capture and compression system.

2 Project Management

2.1 Method of Approach

The design project is currently divided into two sections namely an overall brewery design and a carbon dioxide recycle unit. Both of which we think could be potential independent senior design projects. This means that we may not optimize both processes given our time and budget constraints. As a result, the team decided to focus its attention on developing the carbon dioxide recycle system and optimizing the fermentation process while working with a basic economic analysis of the brewery.

For the overall brewery design, which will be developed in the spring, the team is concerned with determining a good rate law for the fermentation process. Research is still being carried out to figure out
the material components required for the modeling of the batch process of fermentation. Individual residence times in the fermentation tank, wort vessel and the mash tun are dependent on this batch modeling process. Also the team is concerned with the decision on the final alcohol composition of the beer being produced. This decision pertaining to the alcohol content will affect our rate law for the fermentation has been dependent on the team decision to be culturally appropriate and not negatively impact the community. Decisions are to be made about the required hops, yeast strains and malt sugars to be used in the brewery. Lastly, specifications on the filtration systems and the heat exchangers to be used will be made.

Second part of this project which is being tackled simultaneously with the overall brewery design is the carbon dioxide recycle system. For the recycle system, the team worked hard to determine the composition of the off-gas of fermentation. Thus far, tests have been carried out to determine both composition and flow rate and some challenges have been encountered and new experimental approach is being designed. Alongside the experiments, research has been done into possible alternatives for the purification of the off gases to obtain to optimum grade carbon dioxide. Alternatives that arose from research were the use of:

- A molecular Sieve
- Activated Carbon
- Liquefaction and stripping process.
- Timing
- Simple Bubbling of gases through water.
- A possible combination of the above.

The options are then to be tested to get obtain the best optimized alternative design.
2.2 Team Organization

- Members:
  - Alissa Jones, ChE
  - Lota Onwumelu, ChE
  - Nolan Worstell, ChE

- Team Advisor:
  - Professor Wayne Wentzheimer, Calvin College

- Industrial Consultant:
  - Randy Elenbaas, Vertellus Specialties Incorporated

- Customer
  - Barry VanDyke, Harmony Brewing Company

Team Meeting Style:

1. With advisor, scheduled Thursday 10:30am, half hour update:
   a. what has been done in the past week
   b. what should be accomplished in the next week
   c. bringing focus to major goals

2. Work days: approximately twice a week, in computer lab, focus on collaborative writing and research.

3. Visits to Harmony: Bi-monthly, focused on keeping Barry informed on progress and project restrictions

2.3 Schedule

The approach to scheduling was based on the necessity of parallelization, but the project has many interdependencies so many stages cannot be started until the previous stage is done. The work has been held up on the front end due to the slow shipment of the Pitot tube and issues in fabrication of the sampling pipe. In the event of scheduling delays such as these, the project gets pushed back by necessity,
but the overall schedule is designed to keep up with this because the project was initially slated to be done by late February.

The team evenly distributes the work load amongst all of the members. Due to the nature of the project much of the initial work cannot be done in parallel, rather it must be done in a sequential manner until the off gasses from the brewery can be analyzed and initial data obtained. After the initial data is obtained, then the team can work in parallel to simultaneously develop the overall brewery and the CO$_2$ capture and compression system.

2.4 Budget

The budget for this project is projected to be $450. The costs come from two sources, the supplies required for the analytical pipe, and those required for a bench top separations model. The analytical pipe is required to obtain data from Harmony Brewery fermentation tank. This data required for comparing experimental data to theoretical rate models of production. The bench top model, which is to be constructed in the spring, is required to run purification testing on campus. It would allow the team to model the absorption rate of non-permanent gasses to determine the required replacement plan for the activated carbon or molecular sieve. See Appendix I for an overview of expenses.
3 Requirements

The CO₂ capture and compression system needs to meet requirements for food grade carbon dioxide on maximum tolerances of oxygen, hydrocarbons, and sulfuric compounds. Standards on presence of nitrogen will neglected due to its inert nature in the brewing system. The system is also required to fit in the small space available in Harmony Brewery, and the compression unit must fit into the current bottling and proofing system there.

The overall brewery design will be designed for maximum utilization of carbon dioxide recovery and optimized for profitability.

4 Design Norms

4.1 Cultural Appropriateness

Grand Rapids has a wealth of thriving microbreweries and home brewers. This means that art of brewing is somewhat part and parcel of the community and its culture. Our project seeks to develop a more efficient approach at brewing and one that does not impacts the community positively.

4.2 Transparency

The project must be Transparent if the local microbreweries are to benefit from the project. The decisions made as a design team towards the design of the brewery should be easily understood by all interested in adopting our method of brewing. The brewery should have no hazy aspects to its design and should operate on the characteristics of a transparent design. A transparent design should be consistent, reliable and predictable.

4.3 Integrity/Trust

Integrity/Trust must be highly placed as Harmony has entrusted the team to safeguard its trade secret specifications for its beers. Furthermore, our design will be complete in its approach to solving the
problem of carbon dioxide recycle in the brewery. The design will not be missing any important pieces that may compromise the overall brewery in the long run. Understanding the design will be hindered by the method of presentation as it will be logical and easy to follow.

4.4 Stewardship

Stewardship is the overall driving force for the project because it requires that we, as engineers, design a brewery that is as efficient as possible for the scale and that can recycle at least some of its waste streams, i.e. CO$_2$ capture and reuse.

5 Overall Brewery

A brewery consists of several batch systems in sequence. Initial brewing involving the mash tun and wort kettle can be complete in an afternoon, but fermentation, where the conversion of sugars into alcohol and carbon dioxide takes place, requires more than a week for completion. Post production of the beer, including conditioning, filtration, carbonation and bottling, require days of work. Figure 1 on following page is a simple PFD for an overall brewery.
Overall Brewery Design

Proposed CO2 Compression and Purification Phase

Air Lock Vessel
Water
CO2 + aromatics
Compressed CO2 + aromatics
Compressed CO2

Gas Retention Vessel with Pressure Gauge
Water + Sulfides

CO2 Dryer: Activated Charcoal or Molecular Sieve

Compressor

Figure 1: Overall Brewery PFD
5.1 Mash Tun

The mash tun is where the brewing process begins for the average microbrewery. Larger scale breweries can do their own malting—the partial germination and drying of the barley—and grain specialization due to their large spatial capacity, but microbreweries with a maximum capacity of 15,000 barrels/year do not have economic or spatial ability to specialize in this way and thus buy processed malt.

The mash tun consists of a large vessel in which the malt barley is placed into hot water to extract the now water soluble sugars, a result of the malting process. After a residence time of a between 4-6 (Othmer, 1997) hours, the sugary water—sweet wort—is then filtered and heated before heading to the wort kettle.

The design of the mash tun is dependent on the size of the wort kettle. The mash tun should be almost if not exactly the same size as the wort kettle because all of the sweet wort from the mash tun goes to the wort kettle. This means if you are making too much or too little sweet wort in the mash tun then you are wasting sweet wort or you are underutilizing the wort kettle, which is poor stewardship.

5.1.1 Heat exchanger

The heat exchanger is a crucial part of the transfer of the sweet wort from the mash tun to the wort kettle. This is because when the sweet wort is introduced with the hops and adjuncts, non-barley ingredients for flavoring, in the wort kettle it must be up to a 100°C (Othmer, 1997) to avoid lowering the temperature too much so that the humolones or alpha acids in the hops are not extracted in significant quantities preventing the characteristic beer flavor we all know and love.

5.1.2 Filter

The filter is important for two reasons. The first is that it removes the spent grains—the malt barley that has had its water soluble sugars removed—that would cloud the beer after fermentation as well as provide off flavors if left in. The second is that the spent grains can also serve as a minor profit stream as many feed lots and livestock growers use the spent grains as a way to add protein to the animal’s diet.
5.2 Wort Kettle

The wort kettle is where the hops and adjuncts are added to the sweet wort. It is important at this stage to keep the wort boiling as this is the sterilization stage as well as the stage where the humulones from the hops are extracted with the various additional flavors imparted by adjuncts to produce a particular taste in the final product.

All equipment in the brewery must be of the same capacity. Equipment is sized according capacity of the fermentation tanks, and American standards use the Barrel Numbering system. The equipment holding only liquid has a nominal value that is equal to the actual liquid volume. For example, and 8 barrel brewery would have fermentation tanks that hold 8 barrels (250 gallons) of beer, and would have a mash tun and wort kettle with higher volume to hold all 8 barrels of liquid as well as the solids required.

5.2.1 Heat exchanger

This is typically a steam jacket around the wort kettle. The purpose is to keep the wort boiling as the humulones and the other flavor compounds are extracted.

5.2.2 Filter

This is key for keeping the hops seed pods and the various solids from the added adjuncts from reach the fermentation vessel and producing off flavors.

5.3 Fermentation Tank

The Fermentation tank is the reactor of the brewery. This is where the sugars in the wort are converted into alcohol and carbon dioxide. During this process the only thing added is the yeast that causes the fermentation and sterile air so the yeast colony can initially grow before beginning the fermentation.
Throughout the fermentation process, there are two key factors. The first key factor is that the temperature of the fermentation tank must be kept at 69 ± 3 F (VanDyke, 2012) but this exact temperature varies based on the type of yeast (Boulton & Quain, 2001), (Gibson & Prendergast, 2003).

The second key factor is applicable to the carbon dioxide capture and compression part of the process. This key factor is the pressure must be maintained at or near atmospheric (Barry VanDyke). This is important because if the pressure of the gasses gets high enough at the fermentation tank temperature it may cause the inactivation of the yeast strains (Saccharomyces cerevisiae) and cease the alcoholic fermentation (VanDyke, 2012) of the beer effectually ruining the entire batch. (Boulton & Quain, 2001).

After the beer has finished fermenting, typically 10 days (VanDyke, 2012), the green beer (non-aged beer) is filtered with a simple mesh to remove the dead yeast colonies before moving to a conditioning vessel.

When deciding on the number of tanks to use, there are two factors. The first factor is the variety of beers that intend to be brewed at any time. This means that if the brewery is only making a few kinds of beer it makes more sense to buy a few larger fermentation tanks whereas if there are many varieties then it makes more sense to buy more, smaller fermentation tanks. The second factor is the amount of time it takes to clean and perform maintenance on the tanks. For instance, if you buy only a few large tanks, but they need to always be running at full capacity then you should increase the number of tanks so that a tank can be taken offline for maintenance or cleaning since both are required to keep the brewery running.
5.4 Beer Conditioning

The condition vessel serves several purposes. For Ales, this is where the beer is kept for 2-3 weeks, whereas Lagers require 3-4 weeks. Also this is where the beer can be carbonated either by adding in additional new yeast and sugar or by having a bypass stream from the fermentation tank to add fermenting wort directly into the tank.

5.5 Beer Filtration

This is typically necessary when additional yeast is introduced into the beer during the conditioning step or when there are solids that tend to settle out during the conditioning of say a lager.

5.6 Beer Carbonation

5.6.1 Traditional methods

Traditionally beer is carbonated by the addition of yeast to the beer in the conditioning vessel. How this is done is described in the above beer conditioning section.

5.6.2 CO2 Capture and Compression System

The carbon dioxide provided by the capture and compression system can be used in several ways in the brewery, but the two main ways are that it can be used in place of the yeast in the beer conditioning step and/ or it can be used in driving out the oxygen from the bottles, barrels, and kegs before the beer is added in. The main advantage of this system is that, particularly in larger breweries, the implementation of a carbon dioxide capture and compression system can greatly reduce the amount of carbon dioxide that is purchased for use in the bottling process. The additional, and perhaps in the long term greater, advantage is from the decreased pollution of the atmosphere by the additional carbon dioxide release which, as mentioned in the Design Norms section, is one of the key factors for the team approaching this project.
CO2 RECYCLE CONCEPT

Figure 2: Purification and Recycle Diagram

5.7 Bottling Process

The bottling process depends on the shipping medium that is preferred by the company. The two major shipping methods are via bottle and via keg. The methods for adding the beer into each is overall similar, but each can introduce its own challenges.

The major part of the bottling process for either shipping medium is that the container must be washed out with either soap and water or another cleaning solution and then purged with carbon dioxide, typically twice, to remove oxygen. The principle difference between bottling bottles over bottling kegs is how they are cleaned and the amount of carbon dioxide that is needed.

For the kegs, typically the keg is dirty from a previous filling as kegs are generally reused many times before they are disposed of. This means that kegs need additional, perhaps manual, washing before they are ready to be introduced to the bottling line.
None of the additional cleaning is typically needed for bottles. This is because bottles are not typically reused and as such the cleaning is more to remove the minor dirty and debris that has settled into the bottles from the glass fabrication plant en route to the brewery.

6 Task Specifications and Schedule

The team developed a work break down schedule to help track our progress and to give us deadlines and milestones to work with. A link to the work break down schedule may be found at http://www.calvin.edu/academic/engineering/2012-13-team3/documents/wbs. A list of the major tasks for this project may be seen in Table 1 below.

Table 1: Table showing major tasks

<table>
<thead>
<tr>
<th>Task</th>
<th>Degree of Completion</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2 recycle system</td>
<td>50</td>
</tr>
<tr>
<td>Fermentation tank design</td>
<td>10</td>
</tr>
<tr>
<td>Mash and Boiling vessel design</td>
<td>10</td>
</tr>
<tr>
<td>Economic analysis</td>
<td>100</td>
</tr>
</tbody>
</table>

Nolan (ChE) is in charge of managing, updating and maintaining the schedule. The rating rubric employed to keep track of progress may be seen in Table 2 below. It was done as this way to make easy the way team keeps track of its work.

Table 2: Table showing rating scale for major tasks

<table>
<thead>
<tr>
<th>Degree of completion</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Not started</td>
</tr>
<tr>
<td>10</td>
<td>Started</td>
</tr>
<tr>
<td>50</td>
<td>Mid-way through</td>
</tr>
<tr>
<td>100</td>
<td>completed</td>
</tr>
</tbody>
</table>

The project schedule has had a lot of changes this semester because of the lapses experienced in testing off gases. For the spring semester, the team plans to complete the tests and then start design the
purification unit within the carbon dioxide system to obtain an optimum design. Also the fermentation process will be completely modeled and so would all specification for the vessels in the overall brewery.

7 Experiment

7.1 Design Method

Decision matrices were employed for a majority of our decisions this semester. In this report, when decision matrices are presented, the first column contains the design criteria for that given design choice. The second column contains the weight of each criterion. Each design alternative is given a score for each criterion on a scale of 1 to 10 and the scores are summed. The highest total indicates that the best fit design alternative for the team. It is important to note that decision matrices are highly subjective in setting the weights of each design criterion. The team thoroughly and carefully decided on design criteria for each choice, keeping in mind the design norms guiding the project. The shaded column in the decision alternatives is used in this report to help visually illustrate the top design options.

7.2 Design Alternatives

In the construction of the analytical pipe for collection of samples and rate measurement, several alternatives were considered. First were the materials of construction, and second was the method of velocity measurement.

<table>
<thead>
<tr>
<th>Table 3: Materials of Construction Design Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stainless Steel</td>
</tr>
<tr>
<td>--------------------</td>
</tr>
<tr>
<td>Corrosive Resistance</td>
</tr>
<tr>
<td>Ease of Construction</td>
</tr>
<tr>
<td>Inexpensive</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

The design criteria for the materials of construction where purposely chosen to account for the sensitivity of the nature in which we were to run our experiment. We needed a material that will not be corroded by the off gas of the fermentation process and be passive the through the whole experiment.
Also this material has to be inexpensive and be within team budget. The material must also be very easy to work with as team does not have expert metal workman.

<table>
<thead>
<tr>
<th></th>
<th>Pitot Tube with Manometer</th>
<th>Pitot Tube with Digital Pressure Meter</th>
<th>Anemometer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inexpensive</td>
<td>7</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Direct Reading</td>
<td>5</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Closed System</td>
<td>10</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>25</td>
<td>23</td>
</tr>
</tbody>
</table>

In order to figure out the flow rate of the off gases from the fermentation process, a few more criteria were employed. As a team, we agreed that the device must be relatively inexpensive as we are working within a tight budget. The device must be easily made into a close system and the readings must also be easy to obtain.

The team chose copper as material of construction due to the availability of parts. The team chose a pitot tube for rate measurement because the difficulty involved in making an airtight seal for an anemometer was deemed to be prohibitive. An electronic pressure sensor was decided upon for the pitot tube due to ease of reading the measurements for Barry and his staff, and size constraints of the room.

7.3 Testing

Using the sampling pipe, initial data for rate and composition were obtained on a regular brew at Harmony Brewery along with a base line sample of the air in the room.

Important preliminary data was obtained from the first round of testing that will be addressed before the second round takes place.

First is the relevant range of days were samples can be collected was found to be four days. After five days of fermenting, the flow rate of the off gasses is too slow to fill the gas collection bags.

A second critical piece of information gleaned from the initial data collection is that condensing water fills the hosing from the pitot tube to the pressure meter, rendering the pressure readings out of
range of the meter. A small holding tank to collect condensed water and allow the gaseous flow through the meter has been hypothesized as a possible solution to this draining issue.

Third, the GC/MS column, while excellent at detecting trace quantities of high molecular weight impurities, is ill-equip to detect and separate all of the low molecular weight gasses that make up the majority of the sample. If another column is available, it will be tested.

Finally, a second method of determination of reaction rate has been proposed utilizing the main chemical reaction of 1 mol Sugar + Yeast → 2 mol Alcohol + 2 mol CO2. Because alcohol and carbon dioxide are produced in equimolar quantities, alcohol content of the fermentation liquid can be used to calculate the amount of CO2 produced over time.

Figures 4 and 5 depict GC/MS ratios of compounds detected in the current column. Figure 4 shows the full spectrum, illustrating the large region where the light gasses did not separate well, while Figure 5 shows the resolution of the larger molecules which can be detected.
7.4 Recommendation

The majority of the fall semester has been consumed by analytical data collection and interpretation. This process would have taken a lot less time if better analytical equipment were available to the team. One such preferred equipment would be a portable photoacoustic spectrometer. The photoacoustic spectroscopy involves irradiating intermittent light onto a sample and then detecting the periodic temperature fluctuations in the sample as pressure fluctuation. Photoacoustic spectrometer is portable and would permit on site testing (Shimadzu.com). The spectrometer would permit measurement without pretreatment. It is very sensitive and would measure concentration of gases in parts per billion or even in parts per trillion.

A photoacoustic Spectrometer was considered in the early planning stages of the project to determine continuously both rate and composition of the off-gasses from the fermentation process. The spectrometer will cost in upward of two thousand dollars was thus was rejected as an option for this reason. The team decided to use a fabricated device (Analytical pipe) consisting of a pitot tube and digital
pressure reader to calculate off gas flow rate and the also use the GC-MS machine in the Calvin College Chemistry Department for determination of the composition.

8 Business Plan

Economic analysis for the feasibility of an overall brewery was developed with the guidance of the Engineering Business class. As a business, iBrew would have to purchase all of the equipment necessary for the production and plan for a three year scale up of product to full capacity. Along with the economic analysis, study of the brewing market provides perspective on challenges of entering the market with a product, even one as well established as beer.

8.1 Marketing Study

8.1.1 Competitor analysis

Identifying competition in terms of companies that fill the same needs that we do, our competitors are significant in our main product lines, though a few are dominant in the market. Hence there will be a need to strongly differentiate ourselves from these other businesses. However on a broader scale, our competition comes in several forms:

1. The most significant competition is that of Bell’s Brewing Incorporated and Founder Brewing Company, which is smaller than Bell’s but arguably the Michigan craft beer market leader. Having been on the market for a relatively long period of time added to the fact that they are top 50 beer sales in 2011 (Brewers Association, 2012). They have a wide and established distribution network that they utilize to their advantage. Our key advantage in competition with these Breweries is that we aim on providing beer to consumers at the least price. We intend to vigorously undertake new channel and distribution development in addition to deploying aggressive marketing strategies. Also, aggressive advertisement shall assist in our attainment of goals and objectives.
2. Other manufacturers of traditional brews including smaller breweries and brewpubs will also constitute our competitors. They often have access to the local and remote areas and knowledge of these areas. However the products are not as cheap, which is a factor we shall fully exploit. These breweries are as below:

- Schmohz Brewing
- Brewery Vivant
- Hideout Brewing
- Harmony Brewery Company
- New Holland Brewing
- Frankenmuth Brewery
- Arbor Brewing Company
- Short’s Brewing Company
- Atwater Brewery
- Motor City Brewing Works Incorporated
- Royal Oak Brewery
- Dark Horse Brewery
- Arcadia Ales
- Grand Rapids Brewing Company

3. Potential competitors will find it hard matching iBrew as we have planned to provide the cheapest beer at the highest possible quality to consumer. So even though the barrier to entry may be low, our customer base would be defined.

8.1.2 Market Survey

In the process of fermenting beer, sugars are converted into carbon dioxide and ethyl alcohol. In the current process for small scale breweries, the carbon dioxide is vented off and released to the atmosphere. Later, in the bottling process, pressurized carbon dioxide is used to re-carbonate. By utilizing the naturally occurring byproduct carbon dioxide, the carbon footprint of beer making can be reduced and can relieve financial pressure of buying compressed carbon dioxide. The benefit is to the environment. Less carbon dioxide released from our brewery reduces greenhouse gases.

8.1.2.1 Target Market and Motivation

The target demographic for iBrew is Generation Y and the Millennial Generation. Both generations are characterized by environmental consciousness and technological involvement. These
aspects would be highlighted by social media and technology integration in marketing. Customer motivation to buy our product would be for the effect of alcoholic content coupled with a taste unaffected by the recycling process and an environmental motivation to choose our product over the larger carbon footprint competition.

8.1.2.2 Market Size and Trends

Microbreweries will represent 0.69% of national microbrewery beer production. A microbrewery is defined as a brewery with a maximum annual production of 15,000 barrels with 75% sold offsite. Microbreweries therefore compete regionally rather than nationally and in Michigan account for 3.5% (Michigan Brewers Guild) of the total beer production of 6,315,663 (Beer Institute). iBrew would represent 4.5% of Michigan’s microbrewery production.

The craft brewing industry has been a growing part of the modern market. Growth of the craft brewing industry in 2011 was 13% by volume and 15% by retail dollars. (Brewers Association, 2012)

Although overall US beer market was down by 1% in 2011, craft beers are moving up. Thus, the overall market is most affected by large companies that are not doing as well. Brewers Association provides numbers of microbreweries (and other styles of craft breweries) in 2010, 2011, and halfway through 2012.

Table 5: Growth of Craft Breweries Industry

<table>
<thead>
<tr>
<th>Year</th>
<th>Brewpubs</th>
<th>Microbreweries</th>
<th>Regional Craft Breweries</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>1053</td>
<td>615</td>
<td>81</td>
</tr>
<tr>
<td>2011</td>
<td>1063</td>
<td>789</td>
<td>88</td>
</tr>
<tr>
<td>2012 (July)</td>
<td>1072</td>
<td>922</td>
<td>81</td>
</tr>
</tbody>
</table>
8.1.2.3 Advertising and promotion

The message iBrew would like to sell is that buying a “green” beer has a positive impact on the environment, and that small companies can do their part to care for the planet while providing products and services.

Two forms of media will be utilized to get this message across: website design and labeling.

The iBrew company website will be a user friendly way to access quality photos and descriptions on iBrew’s current brews. The site would also emphasize the unique recycling system and list availability of the products in store.

In stores, the way to catch a potential customer’s eye is through labeling. Our simple green label with CO2 bubbles on brown bottles would catch the eye and would display the uniqueness of the product.

10% of revenue is devoted to marketing and would include salaries of marketing consultants and sales employees.

8.1.2.4 Pricing

The desired image of iBrew is to be a contender in the local craft beer market. Craft beers are expected to have a higher price tag than the big name beers, but are also expected to have the high quality and attention to detail associated with a small local business.

Against competitors, image will be a higher factor than price. The aim of iBrew is to be on the level of competitors. A wholesale price of $2.00 would allow for stores to apply a 100% markup to sell at $4.00, a competitive price with Brewery Vivant and Founders Brewing Company.
### Table 6: Pricing per Volume of Product

<table>
<thead>
<tr>
<th>Size</th>
<th>Price</th>
<th>Price per Volume ($/oz.)</th>
<th>Retail or Wholesale?</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 oz. bottle</td>
<td>$2.00</td>
<td>0.17</td>
<td>Wholesale</td>
</tr>
<tr>
<td>12 oz. bottle</td>
<td>$4.00</td>
<td>0.33</td>
<td>Retail</td>
</tr>
<tr>
<td>64 oz. growler</td>
<td>$15.00</td>
<td>0.23</td>
<td>Retail</td>
</tr>
<tr>
<td>15.5 gal keg</td>
<td>$70.00</td>
<td>0.04</td>
<td>Wholesale</td>
</tr>
</tbody>
</table>

A bulk discount will be available where volumetric cost decreases as packaging size increases. Kegs deposits ensure return of the high volume packaging for reuse, the savings of which can be passed on to the consumers. The growlers would be available only on location for refilling, and have a bulk discount applied of $0.10/oz.

Gross profit margin % anticipated for the first three years where product capacity is increasing is tabulated below:

### Table 7: Gross Profit Margin during scale-up

<table>
<thead>
<tr>
<th>Year</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Profit Margin (%)</td>
<td>172.45</td>
<td>199.28</td>
<td>228.6</td>
</tr>
</tbody>
</table>

#### 8.1.2.5 Distribution Strategy

iBrew will sell 75% of product as wholesale and 25% retail. The off-site distribution will be through stores and restaurants. On site purchase of bottles and growlers would be available, most notably during tours. Walking traffic will be limited due to location in the industrial district.
8.2 Cost Estimate

8.2.1 Development

Some costs of development of the CO2 compression and purification system will be incurred during the semester and will be paid for with the senior design budget, outlined on in the Project Management section. Other costs will be specified for the implementation but not bought for the design project. These costs include the cost of a compression system.

8.2.2 Production

For the design and production of a 10,000 barrel/year microbrewery, which is 0.69% of the US market share for microbreweries, Table 8 shows the balance sheet and outlines the annual revenues and expenses. The main source of revenue for the brewery is the total sales of beer which is comprised of the sales of kegs, 12 oz. bottles, and growlers. The additional sources of revenue come from the selling of spent grains and the selling of the growler bottles themselves. The three years are shown so as to model the increasing production of the brewery from 50 to 100% linearly over those three years. The salaries and wages line time comes from the cost of employing 8 employees that is the industry standard for our brewery size (JV Northwest. Inc, 2009) and employing a microbiologist.
<table>
<thead>
<tr>
<th></th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sales</td>
<td>$2,831,583.33</td>
<td>$4,247,375.00</td>
<td>$5,663,166.67</td>
</tr>
<tr>
<td>Selling back spent grains</td>
<td>$852.50</td>
<td>$1,278.75</td>
<td>$1,705.00</td>
</tr>
<tr>
<td>Return on growlers</td>
<td>$2,325.00</td>
<td>$3,487.50</td>
<td>$4,650.00</td>
</tr>
<tr>
<td><strong>Total Revenue</strong></td>
<td>$2,834,760.83</td>
<td>$4,252,141.25</td>
<td>$5,669,521.67</td>
</tr>
<tr>
<td>Salaries and Wages</td>
<td>$619,200.00</td>
<td>$619,200.00</td>
<td>$619,200.00</td>
</tr>
<tr>
<td>Designers</td>
<td>$26,719.66</td>
<td>$26,719.66</td>
<td>$26,719.66</td>
</tr>
<tr>
<td>Supplies</td>
<td>$149,415.07</td>
<td>$224,122.60</td>
<td>$298,830.13</td>
</tr>
<tr>
<td>Yeast</td>
<td>$132.67</td>
<td>$154.00</td>
<td>$205.33</td>
</tr>
<tr>
<td>Bottles</td>
<td>$307,723.25</td>
<td>$461,584.87</td>
<td>$615,446.49</td>
</tr>
<tr>
<td>CO2 Purchased</td>
<td>$9,380.00</td>
<td>$14,070.00</td>
<td>$18,760.00</td>
</tr>
<tr>
<td>Distributing</td>
<td>$3,989.39</td>
<td>$3,989.39</td>
<td>$3,989.39</td>
</tr>
<tr>
<td>Advertising</td>
<td>$283,158.33</td>
<td>$424,737.50</td>
<td>$566,316.67</td>
</tr>
<tr>
<td>Rent Expense</td>
<td>$9,600.00</td>
<td>$9,600.00</td>
<td>$9,600.00</td>
</tr>
<tr>
<td>Utilities - electric, water, phone</td>
<td>$22,200.00</td>
<td>$33,300.00</td>
<td>$44,400.00</td>
</tr>
<tr>
<td>License</td>
<td>$1,012.99</td>
<td>$1,012.99</td>
<td>$1,012.99</td>
</tr>
<tr>
<td>Alcohol Tax</td>
<td>$21,500.00</td>
<td>$32,250.00</td>
<td>$43,000.00</td>
</tr>
<tr>
<td><strong>Depreciation</strong></td>
<td>$168,934.14</td>
<td>$289,516.94</td>
<td>$206,764.03</td>
</tr>
<tr>
<td><strong>Total Operating Expenses</strong></td>
<td>$1,622,965.50</td>
<td>$2,140,257.95</td>
<td>$2,454,244.71</td>
</tr>
<tr>
<td>Net Income before interest and taxes</td>
<td>$1,211,795.34</td>
<td>$2,111,883.30</td>
<td>$3,215,276.96</td>
</tr>
<tr>
<td>Interest</td>
<td>$69,197.42</td>
<td>$69,197.42</td>
<td>-</td>
</tr>
<tr>
<td><strong>Budgeted Net Income</strong></td>
<td>$1,142,597.91</td>
<td>$2,042,685.88</td>
<td>$3,215,276.96</td>
</tr>
</tbody>
</table>

Revenue is calculated as the selling of all of the volume produced in the form of bottles, growlers and kegs, along with selling back of grain to farmers and redeeming the return on the midsize growler bottles. Expenses come in the form salaries and wages for the 8 workers, 3 designers and microbiologist, the cost of materials including malt, hops, and yeast, the cost of utilities which includes the ingredient of water, the 10% of revenue devoted to marketing, the alcohol tax, among others. The cost of equipment was estimated from Seader’s Method 3 formulas except for the Mash Tun/Wort Kettle unit for which a
The following table outlines the equipment cost estimations and their sources:

<table>
<thead>
<tr>
<th>Machine</th>
<th>Source or Equation from Seeder Method 3 Estimation</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mash Tun / Wort Kettle</td>
<td>Quote (Alibaba.com)</td>
<td>$32,000</td>
</tr>
<tr>
<td>Storage tank</td>
<td>$14,300</td>
<td></td>
</tr>
<tr>
<td>Fermentation Tank</td>
<td>Modeled as Storage tank</td>
<td>$14,300</td>
</tr>
<tr>
<td>Compressor</td>
<td>$44,700</td>
<td></td>
</tr>
<tr>
<td>Refrigerator</td>
<td>$5,300</td>
<td></td>
</tr>
<tr>
<td>Pump</td>
<td>$38,000</td>
<td></td>
</tr>
</tbody>
</table>

9 Acknowledgements

The team would like to acknowledge the efforts of Barry VanDyke who has been invaluable in getting the project to this stage and allowing the team to model his brewing process. Furthermore, the team would also like to acknowledge Phil Jasperse, Bob Dekraker, and Wayne Wentzheimer for their advice and assistance in directing the project.

10 Conclusion

The preliminary off gas composition and flow rate testing has been performed and more testing is still required from the brewery, and when composition is determined sufficiently, testing of pilot plant purification units can be done on campus. Simulations of an overall brewery will be designed on Super Pro Designer to determine the relationship between fermenter size, reactor time, and alcohol and CO2 content.

The team decided that the optimum scale for the brewery was 10,000 bbl. /year. This choice was based off the desire to operate the brewery as a microbrewery which is defined as having a maximum
capacity of 15,000 bbl. /year. (Sound Brewing Systems, Inc) The reasoning behind this choice is that by operating a microbrewery, the costs are kept lower, for tax purposes, and the beer can still be sold at a premium by being classified as a craft beer.

Based on preliminary cost estimates for the 10,000 bbl. /year case, the brewery with recycle system will generate an annual profit of just over $1.1 million for the first year, growing to $3.2 million in three years. This profit comes from the premium price that can be charged for a craft beer and the decreased alcohol tax by being a microbrewery. Thus the team recommends that the development of the brewery be continued.

11 Resources


http://en.wikipedia.org/wiki/Photoacoustic_spectroscopy


VanDyke, B. (2012, October 10). (T. iBrew, Interviewer)


www.victorybeer.com
Appendices

I Overview of Team Expenses
Appendix I

Overview of Team Expenses

Supplies for Analytical Pipe

- Incurred thus far:
  - $58 pitot tube (Zoro Tools)
  - $25 pipe fittings (Lowes)

- Expected Expenses:
  - $50 second pipe (Lowes)
    - Including fittings and additional pipe

Supplies for Bench Top Model:

- Expected Expenses:
  - Mixed gas tank
    - $150
    - 2990 cu.in. at 2400 psi
    - Airgas.com
    - Difficult to get a price estimate, could be low
      - Added $50 for uncertainty
  - Drying Agent
    - Indicating Drierite, 1 lb
    - $11
  - Activated Carbon
    - http://www.buyactivatedcharcoal.com
    - 4lb = 1 gal
    - $30
  - Molecular Sieve
    - http://www.y-carbon.us
    - $50/g