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Product Carbon Footprint of Goose Island Brewery 312 Beer Keg

Carbon emissions from agriculture to delivery at the pub for a keg of 312 beer.

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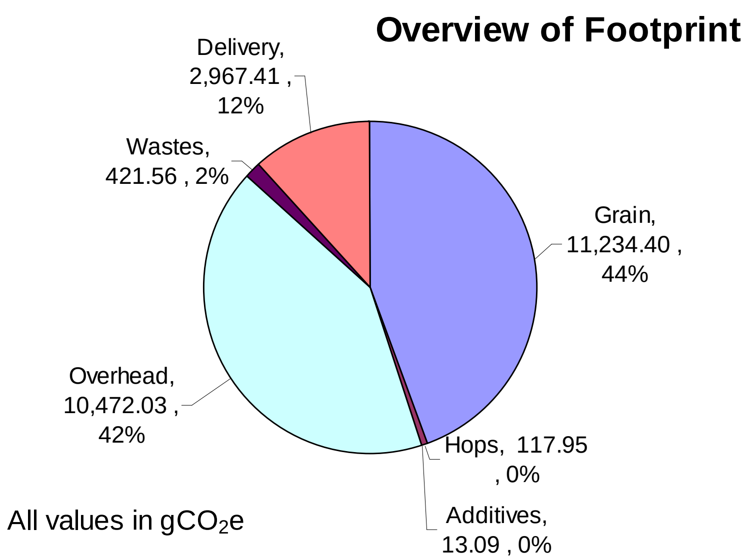
Product Carbon Footprint for a single keg of 312 beer.

A Life Cycle Assessment of beer focused on Greenhouse Gas emissions.

Executive Summary

The product footprint of a keg of 312 beer accounts for the full life cycle emissions of greenhouse gases. From agriculture, the growing and harvesting of the primary ingredients of the beer, to the consumption at a retail location, all of the activities are assessed for the emissions of gases contributing to global warming. Of the processes measured agriculture and operations account for the majority of the emissions at 86% of the total emissions coming from those two activities (see figure below). As is expected from the literature agriculture has a significant impact both from the fertilizers used and from current soil management practices which can release significant amounts of CO_2 into the atmosphere. The second highest source of emissions is combustion of natural gas used in the brewery to heat water and from direct carbon dioxide emissions when CO_2 is used to carbonate the beer and pressurize tanks. Significant gains in the efficiency of water use will reap benefits not only on the water footprint but also in the energy use in the brewery.



Definition of Terms

Carbon Footprint – The carbon footprint, or embodied carbon, of a product or service is the total amount of GHG's emitted across the life cycle of a product. Through there are non-CO_2 GHGs that are included in the carbon footprint, the term arises from the most significant GHG: CO_2 (carbon dioxide).

CO_2e – **Carbon dioxide equivalent**. A unit of GHG emissions, including non – CO_2 gases, where the impact of the emission of a substance is calculated based on the equivalent mass of CO_2 emissions.

ecoinvent database – A database of life cycle inventory data compiled by a Competence Centre of ETH, PSI, Empa and ART - suppliers of consistent and transparent life cycle inventory (LCI) data of known quality.

GHGs or Greenhouse Gases – Three of the "Kyoto" gases regarded as most significant in terms of their climate impact: carbon dioxide (CO_2), methane (CH4) and nitrous oxide (N_2O).

GWP or Global Warming Potential - GWP is a measure of how much a given mass of greenhouse gas is estimated to contribute to global warming. It is a relative scale which compares the gas in question to that of the same mass of carbon dioxide (whose GWP is by definition 1). In this report the 100-year global warming potentials are used as defined in the Fourth Assessment Report of the International Proramme on Climate Change (IPCC) in 2007.

NBB – New Belgium Brewing Company of Fort Collins, Colorado

WRI GHG factors – Emission factors that are used to calculate the emissions from certain activities such as transportation of goods, the generation of electricity or burning of fossil fuels. These factors can be found at the GHG Protocol Initiative web site at: http://www.ghgprotocol.org/

Introduction

LCA and Scope

A product carbon footprint is essentially a Life Cycle Assessment (LCA) with a focus on the emission of Greenhouse Gasses (GHG). In a LCA the impacts of a product are assessed by measuring the impact of all the materials and processes used in the life of a product, so called cradle to cradle impacts. In fact there are several variations of LCA each of which encompasses a subtle variation in scope and impact measurement. A typical LCA is composed of several steps, goal and scope determination, inventory analysis, and impact assessment. The extent of the inventory and impact assessment is determined by the scope and goals of the project. For short introduction to LCA, its benefits, limitations and a discussion of some LCA variants see http://en.wikipedia.org/wiki/Life_cycle_assessment.

This study is in fact one of the variants where the goal is to understand the Carbon Footprint for a keg of 312 beer. The scope for this project includes the impact from growing and harvesting of wheat, barley, and hops, the chemical additives to the beer, chemicals used in the processing of beer, the operations at the brewery, distribution and storage of a keg at the bar. The study does not include staff commute to work, the transport of the consumer of the beer to the bar or the bar building. The diagram below (Figure 1) illustrates all the operations included in the LCA.

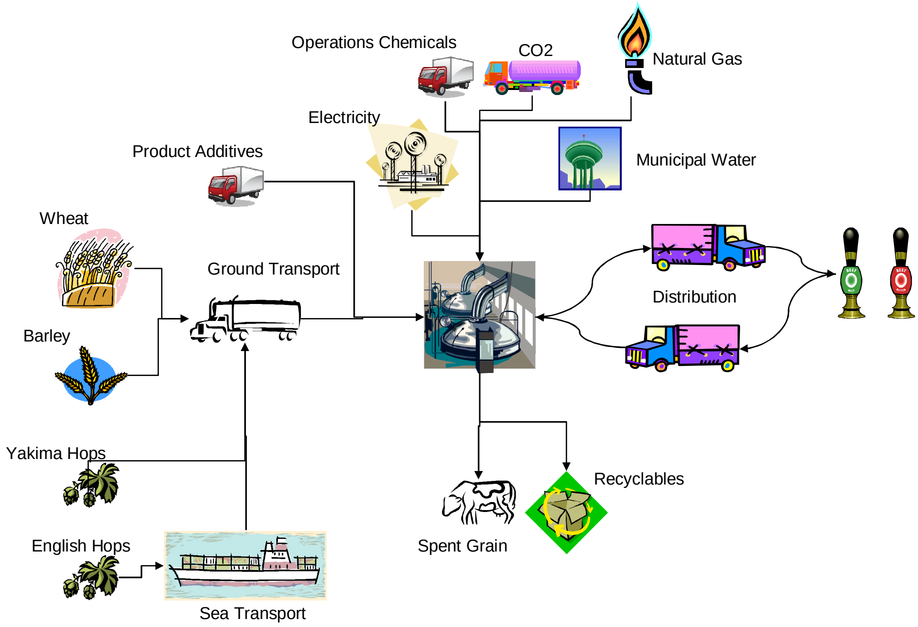


Figure 1 Schematic of Beer Life Cycle

There are two sets of inputs to the brewing process. The first are contained in the recipe for the beer currently being brewed and the second are chemicals used for general operations and are classified as process overhead for this report. Typically several batches or turns are brewed to fill a fermentation tank. In the case of 312 the recipe is for one of 5 turns of 65 bbls each used to complete 300bbls of final product. Inputs included malted barley, torrified wheat, three types of hops (First Gold, Liberty and Cascade), Gypsum, phosphoric acid, yeast and oxygen. Caustic, peracetic acid, Carbon Dioxide, electricity, water and natural gas are also used during processing. Wastes include cardboard from shipping, bags from gypsum, wheat, and hops, spent grains and waste water. The spent grains, including spent hops, are sent to a farm for cattle feed. The cardboard and paper are recycled. Kegs and the skids are used multiple times and are rotated through the brewery, distributor and bar several times per year. To the extent that sales, accounting, manufacturing personnel, and other site operations are included in the utilities calculations, natural gas, electricity and water, they are also allocated to the manufacture of beer.

Some materials used in small quantities were not included in they study. Yeast is started from a small stock, increased in volume through growth and introduced into the fermentation vessel. Some of the yeast grown during fermentation is used in subsequent batches of beer. The impact from yeast is expected to be negligible and is not included in this report. Filter media, glycol for cooling systems, labels used on the kegs and the creation of the equipment in the brewery were also not included.

Introduction to Beer LCA

There have been several beer LCAs conducted and as is traditional for LCA a multi-attribute impact assessment was completed which included multiple aspects of sustainability. Several of these studies were reviewed in a report by The Climate Conservancy in a project for New Belgium Brewery[1] (NBB). The NBB report focused on a 6-pack of Fat Tire Amber Ale. The total emissions were 3,188.8 grams of CO_2 equivalents (gCO_2e). Of those emissions 173.0g or 5.4% were from operations, 1,531.3 gCO_2e or 48.0% were from upstream activities (ingredients and packaging), and 1,484.6 gCO_2e or 46.6% were from downstream emissions (distribution, retail, storage, disposal of wastes). Clearly the major impacts are not from brewery operations but from processes both upstream and downstream of the brewery itself. Another study focused on Italian Lager Beer was released in 2008 and was not included in the NBB report.[2] In the Italian Beer LCA as in the NBB study the primary impacts were in the life cycle stages outside of brewery operations. As is typical of industry practice for general LCA studies the impacts were assessed using one of several methods that take into account multiple variables that are not directly comparable such as recyclability and land use. In the Italian study the Eco-Indicator '99[3] method was used. As in the NBB study beer production was not the most impactful stage. In the Italian study barley cultivation was considered "quite significant" mostly because of the large land area required. The water efficiency was reported separately for kegs, 7.01 L/L and bottles, 7.87 L/L. The higher efficiency for water use in kegs was reported to be from lower water use in cleaning and lower waste when filling kegs. In general beer in kegs caused lower damages and the overall environmental load was about 68% lower than for bottles.

Wherever possible the sources for base data were the suppliers within the Goose Island supply chain. Three of the suppliers queried were able to provide detailed information on their process and the GHG emissions or enough information to calculate GHG emissions. If data was not available from suppliers directly several other sources were used including the NBB report, ecoinvent reports, the GHG Protocol Initiative, and published reports in the literature.

Upstream

Barley Malt **10,325.0 gCO_2e**

Growth and harvesting 7,743.4 gCO_2e

Barley for Goose Island is malted by Canada Malting Co. in Calgary, Alberta and is grown and harvested within 125 miles of the malting facility. Specific information on the practices by the farmers in the Calgary area is not available. However general US national statistics and studies in the US were used in the New Belgium Brewery study and can be used as a substitute in this study. Barley agriculture results in the emissions of GHG's during the production of seed, fertilizers, pesticides, soil amendments, the operation of farm equipment (including irrigation) and emissions from the soil. References [4] are a sample of the most often quoted references from the NBB carbon footprint. The table below shows the contribution of each of the stages to the overall impact of barley agriculture based on the agriculture impacts in the NBB report.

Table 1 Barley Agriculture Impacts

Barley Agriculture	gCO_2e/lb	gCO_2e/312 Keg
Seed Production	29.6	791.4
Agricultural Machinery	35.4	948.5
Irrigation	45.2	1209.7
Fertilizer and Soil Amendments	90.5	2421.4
Pesticides	0.0	0.0
Soil Emissions	88.7	2372.3
Total	289.4	7743.4

Based on the NBB results for emissions per pound of Barley produced the 20 lbs of malted barley per keg of 312 beer results in 7,743.4 gCO_2e.

Malting 1,806.0 gCO_2e

The Malting of barley consists of steeping in water, germination, drying and roasting of the barley. Each of these steps uses some energy. Data was collected for this study from one supplier, Canada Malting Co, and is compared to the reported results from the NBB report in Table 2.

Table 2 Impacts from Malting Barley

Company	gCO_2e/lb malted barley

Barley Malting Rahr	143.4
Barley Malting Coors	164.0
Barley Malted Canada Malt	90.3

For the 20 lbs of malted barley per keg of 312 the emissions are 1,806 gCO_2e

Transport 434.5 gCO_2e

Barley is grown for Canada Malting through a local network of farms that are generally within 125 miles of the malting house in Calgary, Alberta, Canada. The malted barley is transported by rail to South Holland near Chicago where the malted barley is transloaded to bulk truck for delivery to Goose Island. The distance by rail from Calgary to South Holland is approximately 1,600 miles and the distance from South Holland to the brewery is about 25 miles.[5] Transportation impacts are calculated based on WRI GHG factors for diesel truck transportation on a mile-weight basis.[6] The total GHG emissions for transport are 434.5 gCO_2e.

Wheat **1246.6 gCO_2e**

Growth and Harvesting 824.9 gCO_2e

The original sources on barley agriculture were for the most part non-specific to barley and covered grain agriculture in general. Based on that information the growth and harvesting of wheat is expected to have similar impacts to barley and the barley results will be used for the growth and harvesting of wheat. The results for each stage in wheat agriculture are in Table 3. Each keg of 312 uses 2.8 lbs of torrified wheat which accounts for 824.9 gCO_2e.

Table 3 Impacts from Wheat Agriculture

Wheat Agriculture	g CO_2e/lb	312 keg
Seed Production	29.6	84.3
Agricultural Machinery	35.4	101.0
Irrigation	45.2	128.9
Fertilizer and Soil Amendments	90.5	257.9
Pesticides	0.0	0.0
Soil Emissions	88.7	252.7
Total	289.4	824.9

Torrification 228.5 gCO_2e

Torrification of wheat is a process of heating the wheat to break down the cell walls and pregelatinize the grain. This can be accomplished in several different ways; cook the grain in an oven, cereal cook the grain, or microwave it. No specific information on the energy used during torrification was collected. According to Canada Malting, torrification should take a little as 50% the energy of malting.[7] Using 50% of the energy for malting as a rough estimate for torrification the impact from torrification is 228.5 gCO_2e.

Transport 190.4 gCO_2e

Torrified wheat is packaged in 25kg(55.1lbs) bags and shipped by truck from Fergus Ontario to the brewery directly, about 491 miles. Each keg uses 2.8 lbs of wheat and the resultant allocation of the paper bag used to package the wheat is 0.03 lbs for a total shipping weight of 2.83 lbs and an impact of 190.4 gCO_2e.

Packaging 2.76 gCO_2e

The impact from the packaging is primarily in the manufacture of the paper for the bag which is an energy intensive process. Data for the manufacturing of cardboard from virgin material is used as the bags and cardboard have a similar weight, color, and consistency. Data is taken from the EPA report on the life cycle of materials for management of municipal waste.[8] The bag weight is 0.56 lbs and when allocated to a keg is 0.03 lbs accounting for 2.76 gCO_2e

Hops 117.4 gCO_2e

Hops are supplied to Goose Island from three suppliers in the Yakima Valley region of Washington State, S.S. Steiner, Hop Union and Brewers Supply Group and from the UK by Hops from England. Three different varieties of hops are used in 312 beer, Liberty and Cascade which are grown in Washington and First Gold which is grown in England. In each keg there are about 0.008 lbs of First Gold, 0.025 lbs of Liberty and 0.083 lbs of Cascade hops.

Growth and harvesting 69.2 gCO_2e

Hop agriculture has the same impact categories as for barley, machinery, irrigation, fertilizer and soil amendments, pesticides and soil emissions. Data on the agriculture stage is taken from the NBB report[9] and are presented in the table below. As in the barley section selected primary references are listed.[10]

Table 4 Impacts from Hops Agriculture

Hops Agriculture	g CO_2e/lb	312 keg
Agricultural Machinery	216.94	25.39
Irrigation	236.66	27.69
Fertilizer and Soil Amendments	118.33	13.85
Pesticides	0.00	0.00
Soil Emissions	19.72	2.31
Total	591.65	69.23

For the 0.116 lbs of hops of all varieties used in a keg of 312 the impact is 69.2 gCO_2e of emissions.

Processing 3.0 gCO_2e

Information on the processing of Hops was supplied by Brewers Supply Group and Steiner. Two of the varieties of hops, Liberty and Cascade are harvested in the Yakima valley of Washington state. Brewers Supply provided information on Cascade hops and Steiner a generalized hop processing impact. Processing is likely similar for all the varieties of hops. Hops are processed into T90 pellets after kilning and cooling. The pelletized hops are then stored frozen in a regional cooler awaiting Goose Island to order them. They are shipped out 20 boxes to a pallet and combined with other Goose Island orders from other dealers to ship to Chicago on the same truck. Steiner supplied enough information to calculate a carbon footprint for hops processing. For Steiner 25.8 gCO_2e are produced for every pound of hops processed, compared to estimates in the NBB report of 177.5 gCO_2e/lb of hops.[11] Using the Steiner impact numbers for all of the 0.116 lbs of hops produces an impact of 3.0 gCO_2e. Refrigeration, a potentially large source of GHG emissions, is not included in this report because of limited information from the suppliers.

Transport 44.2 gCO_2e

Hops are transported from two different locations, the Yakima Valley area of Washington State, and England. Distances are calculated using Google maps for travel between Yakima, WA and Chicago giving distance of 1987 miles by truck. For hops sourced in England transport was estimated as 2978 miles by boat from Liverpool to Newark,[12] 779 by rail fro Newark to Chicago, and 20 miles on the ground for final delivery to Goose Island. The weight of the box was also included in the transport impact. The total impact from transportation is 44.2 gCO_2e.

Packaging 1.0 gCO_2e

Packaging is in two parts, a multilayer plastic and foil laminate bag and cardboard box. Information on the foil bag was not provided by Steiner. The impact from manufacture of the box was found in the EPA report already mentioned[13] and accounts for 1.0 gCO_2e per keg.

Gypsum 8.8 gCO_2e

Gypsum Mining 5.9 gCO_2e

Gypsum is added to the water to maintain the correct ionic content. The gypsum used is Terra-Alba from USG. This gypsum is mined and processed in Southard, Oklahoma and distributed through VWR. Gypsum is mined as a mix of anhydrate and dihydrate forms. The dehydrate form is used for this application and does not require any thermal processing only purification and grinding.[14] Inputs to the mining process are diesel for mining machinery and electricity.[15] Although the data is for a Swiss mining operation it is expected that the impacts will be similar for an operation in the US. Total emissions from the mining of Gypsum are 5.1 gCO_2e. The gypsum is transported in paper bags that weigh 0.42 lbs each the manufacture of which resulted in at least 0.8 gCO_2e emissions.[16] Delivery of the bag to the Gypsum plant is not included in the transportation.

Transportation 2.9 gCO_2e

The Gypsum is distributed by VWR which has a distribution hub in Batavia, IL. This location has been used to calculate the distribution distance for the gypsum. The impacts from the distribution facility will not be included in this report. Transportation of the Gypsum from the plant in Southard, OK to Batavia, IL is 845 miles resulting in 2.8 gCO_2e in emissions and transportation from Batavia, IL to the Brewery is 40 miles resulting in 0.1 gCO_2e in emissions.

Phosphoric Acid 3.5 gCO_2e

Manufacture 2.8 gCO_2e

Industrial grade phosphoric acid is produced from phosphate rock in a two step process starting with the mining of rock which is then processed into fertilizer grade phosphoric acid (70% in water) and further purified into industrial grade phosphoric acid (50%). Calculations of the impact from phosphoric acid manufacture are taken from the ecoinvent reports on chemicals[17] with energy and fuel sources modified for US production. Goose Island used 1.5 liters of 50% phosphoric acid in their recipe which has a mass of 0.56 lbs and results in emission of 2.8 gCO_2e.

Transportation 0.7 gCO_2e

Since approximately 65% of the production and processing of phosphate rock in the US is in Florida[18] transportation by truck from central Florida was used in this calculation. This is almost certainly an underestimate since it is possible the phosphate rock was mined from another location and processed some distance from the mine. The distance from central Florida to Chicago is about 1170 miles or 0.7 gCO_2e.

Oxygen **0.81 gCO_2e**

Manufacture 0.81 gCO_2e

There are several liquid air distillation plants in the Chicago area that could be supplying liquid oxygen to the supply chain. Oxygen is produced based on compressing, liquefying and distillation of air. Air separation via distillation is a well established process and uses less than 3.5x10-3 kWh of electricity per gram of liquid oxygen produced. One keg uses about 0.28 grams (0.07 lbs) of oxygen accounting for 0.81 gCO_2e emissions.

Transportation <0.01 gCO_2e

Oxygen is liquefied in the Chicago area, transported to Racine or Waukesha Wisconsin for purification and bottle filling then to MedOx for distribution to Goose Island.[19] Although exact details are not clear the distances involved are not large, about 176 miles, and account for less than a tenth of a gram of CO_2e emissions.

Cylinder size commonly used is Airgas 200 or similar cylinder which weighs 106 lbs empty[20] and contains 7,851.5 g of oxygen. Each keg uses 0.38 grams of oxygen or less than 0.5% of a bottle of oxygen. 0.5% of 106lbs is about 0.53 lbs of the weight of the bottle to transport the oxygen used in a keg of beer. This contributes a trivial amount of GHG emissions due to transportation and will not be included in the calculations.

Whirlfloc

Whirlfloc is a complex mixture of Irish Moss and purified Kappa carrageenan that encourages the precipitation of haze causing materials such as proteins and Beta glucans. Ingredients listed for Whirlfloc T included Refined and Semi-refined Carrageenan Powder, Adipic Acid, Sodium Carbonate, Sodium Bicarbonate and Magnesium Silicate. Specific data on the supplier of Whirlfloc , Kerry Bio-Science, and the processing of Whirlfloc was not collected.

Steel Keg **229.0 gCO_2e**

A keg is constructed primarily from stainless steel. Steel is a commodity that has been well studied and typically contains as much as 80% recycled content. For this study information on the GHG emissions of steel manufacture were taken from the 2005 Sustainability Report of the World Steel Industry found on the World Steel Association web site.[21] In that report GHG emissions were reported as 1.7 tonneCO_2e / tonne of raw steel. The number reported here does not include the fabrication of the keg which will add an additional carbon dioxide emission to the footprint thus this is probably a low side estimate of the GHG emissions. A steel keg weighs 29.7 lbs empty and has an expected life of 100 uses. Allocated to a single use, 0.3 lbs of steel contributes 229.0 gCO_2e to the overall footprint.

Wood Skid **57.6 gCO_2e**

Kegs are transported on hardwood skids which carry four kegs per skid and are reused on average 6-8 times per year with an anticipated life time of 75 uses. Wood is harvested from forests and therefore the carbon in the wood does not contribute to the GHG emissions. However the processing of the wood, cutting, drying, milling, and transportation to the user does use energy and has a carbon footprint. Data for the impact of wood is taken from a 2006 report by The Heinz Center on the pulp, paper and wood industries.[22] Each skid weighs 47 lbs which allocated to a single use for a single keg is 0.16 lbs of wood or carbon emissions of 57.6 gCO_2e.

Caustic **612.6 gCO_2e**

Manufacture 611.9 gCO_2e

Caustic is manufactured during the electrolysis of salt, a process that also produces chlorine and hydrogen. There are two main processes for the generation one of which uses mercury and the other using a membrane technology. Since we were not able to trace the actual source of caustic for Goose Island, a Dow chemical production at a plant in Freeport Texas using membrane technology will be used to assess the amount of GHG emitted during processing. Data from ecoinvent on the membrane process is available for a plant in the UK. This data is used with modification to the US electrical grid for electricity impacts. Caustic was estimated by dividing the total usage per year by the production for the basis year. This resulted in 231.2 g of 50% caustic solution being allocated to a keg of 312 or 611.9 gCO_2e of GHG emissions.

Transportation 0.7 gCO_2e

Much is unknown about the locations of both the salt mine and the actual manufacturing facility. It is likely that the salt used in the manufacture of caustic is mined locally or even at the manufacturing plant. Transportation of salt to the plant is short and has a minimal carbon footprint if any. If again we use the Freeport TX plant as the manufacturing site transportation of caustic by truck would be about 1221 miles or a carbon emission of 0.7 gCO_2e.

Peracetic Acid 7.28 gCO_2e

Manufacture 7.28 gCO_2e

Manufacture of peracetic acid is through the reaction of hydrogen peroxide and acetic acid. Hydroxysan PA is a solution of 5.6% peracetic acid and 26.5% hydrogen peroxide in water. Peracetic acid is a one to one reaction of acetic acid with hydrogen peroxide. The impact from 1.5 grams of acetic acid and 11.8 grams of hydrogen peroxide is approximately 7.28 gCO_2e.[23] This is almost certainly an underestimate since transport of the individual ingredients, the impact from raw materials and the reaction/processing impacts are not included.

Transport

The location for manufacture of peracetic acid is not know and is not included in this study.

Carbon Dioxide 2,756.1 gCO_2e

Operations Releases 2,068.4 gCO2e

The carbon dioxide generated from fermentation of beer originates from atmospheric CO_2 fixed by plants and is therefore not included in the CO_2 releases during operations. Carbon dioxide is purchased however for use both to carbonate the beer and as a purge gas in the tanks used for the brewing, fermenting and aging processes. The purchased CO_2 is a byproduct of the hydrogen producing Steam Methane Reforming (SMR) process at Praxair in Whiting, IN. The SMR process involves methane reacting with steam to produce syngas (a mixture primarily made up of hydrogen and carbon monoxide). In the second step, CO produced in the first reaction is reacted with steam to form hydrogen and carbon dioxide. Praxair takes the CO_2 off gas, processes, purifies and redistributes the resulting food grade CO_2. Praxair delivers tank truck loads on a regular basis. The amount used for a keg of beer was estimated from the total amount used in a year, roughly 909,000 lbs, divided by the total production of 99,777 barrels (bbl) of beer in 2008 for a contribution of 4.56 lbs (2,068.4 g)of CO_2 per keg.

Manufacture 687.7 gCO2e

From the NBB report it takes about 400kWh per tonne for the liquefaction of Nitrogen. Because of a lack of data liquefaction of Nitrogen was used as a surrogate for CO_2 manufacture. The carbon generated by creating the carbon dioxide is probably not less than this amount based on the expected trade-offs between purification and processing of the CO_2 which is missing from the calculation and the increased energy needed to liquefy nitrogen. Given these approximations about 687.7 grams of CO_2 are created in the manufacture of 2,068.4 grams of CO_2 required for one keg of beer.

Transport 0.2 gCO2e

Transportation adds an additional carbon load from the fuel used for truck transport. CO_2 is transported in low-pressure tank trucks in roughly 15,000lb loads 72 times per year. The plant location is in Whiting, Indiana which is 21 miles from the Brewery. The CO_2 emitted from transportation of 4.56lbs of CO_2 accounts for an additional 0.2 gCO_2e.

Operations

Electricity 0 gCO_2e

Goose Island used approximately 425,452 kWh to produce 99,777bbl of beer in 2008. The electricity used in the brewery is generated from wind energy, a renewable resource that does not emit carbon dioxide. If the energy used was generated using the Midwest mix of generation facilities approximately 1,779.6 gCO_2e would have been added to the carbon footprint for a keg of 312.

Natural Gas 6,693.4 gCO_2e

Combustion 5,848.7 gCO_2e

Natural gas is used for the generation of steam used in process heating. Goose Island uses two fire tube boilers to generate steam used to heat a hot water tank which is in turn used to heat processing tanks. Carbon dioxide, methane and nitrous oxide are all emitted from this process. Calculation of the total CO_2e from a boiler was performed using the GHG Protocol Stationary Combustion Tool found at the GHG Protocol Initiative web site.[24] This tool does not account for GHG emissions from mining, processing, storage or delivery of gas to the facility. The brewery used about 21,806,490 cubic feet of gas which allocated to a keg of beer is 109.3 cubic feet or accounts for an emission of 5,848.7 gCO_2e.

Mining and Delivery 844.7 gCO_2e

The mining, processing, storage and delivery of natural gas accounts for approximately 15.6 g CH4 emissions for every kilogram of gas delivered to Goose Island.[25] Based on the use of 109.3 cubic feet of gas approximately 33.7g of methane was released upstream of the Goose Island facility. Since methane is a much stronger GHG than carbon dioxide (methane GWP 25) methane emissions result in an additional 844.7 gCO_2e in emissions.

Water 116.0 gCO_2e

Water is supplied by the City of Chicago Department of Water Management through a standard treatment of Lake Michigan water. The carbon emissions from water purification and pumping are from electricity use in the plant. The electricity used during water purification varies from facility to facility depending in part on the amount of pumping required. In the NBB report water was provided to NBB by Fort Collins and used about 431 kWh per million gallons of water. Water purification in the ecoinvent report for water in Europe used about 1,476 kWh per million gallons water.[26] Goose Island uses approximately 18,768,260 gallons of water per year which when allocated to a keg is about 94.0 gallons water used to produce each keg. Using the higher ecoinvent value for energy use in water purification gives carbon emissions of 116.0 gCO_2e per keg of 312 beer. Even using the higher number for energy use in the European water treatment facility the amount of GHG emissions is relatively small.

Sewage 295.5 gCO_2e

Of the water brought into the brewery about 11,468,448 gallons are sent to the Municipal Water Reclamation District of Greater Chicago (MWRD). Over 61% of the clean water used by the Brewery is eventually discharged into the sewer. Waste water includes waster from cleaning, overflow, and some waste beer including beer with waste yeast. The emissions resulting from waste water treatment include the electricity used during processing but not the CO_2 from digestion of the waste solids. All solids from the brewery are from non-fossil sources and so are not included in the GHG emissions. Allocated to a keg waste water is 57.5 gallons resulting in an emission of 295.5 gCO_2e.

Spent Grain 1.2 gCO_2e

Spent grain and hops are collected and sent to a farm in Peotone, IL to be used as animal feed. There are several ways to account for the emissions from the spent grain. If the grain is sold to the farmer it is then considered a co-product of beer manufacturing and the CO_2 burden allocated by weight or value to both the beer and the animal feed as products. At the same time the nutritional value of the spent grains is not the same as unprocessed grain and so it is not a direct replacement for fresh grain. If the grain is considered a by-product then the full burden of transport of the grain is considered part of the beer footprint as is the full impact of growing and processing the grain. In the NBB report the spent grain was considered a co-product and the CO_2e emissions from the grain after use in the brewery was not included in the footprint. However it did not appear as though the emissions from growing and harvesting the grain were split between beer manufacture and animal feed "manufacturing" in the NBB report.[27] For this study of 312 kegs we will account for the CO_2 emissions for spent grains as a by-product from the process not a co-product. As such only the transportation to the farmer will be considered since the operations at the farm are independent of the source of grain. Given the distance from the Goose Island Brewery in Chicago to Peotone is about 47 miles and using the total weight of all grains and hops used in the brewing a total of 23.1 lbs per keg the carbon emissions from trucking the spent grain to Peotone is 1.2 gCO_2e. This is probably an underestimate as the grain is trucked wet and would probably weigh more however the total amount is relatively small and will probably not significantly contribute to the overall carbon footprint.

Recycled Materials 124.8 gCO_2e

Recycled materials are assessed based on an EPA report on waste management options in the US.[28] In this report the different options for handling of waste materials are assessed from a life cycle perspective and the relative GHG impacts of the waste handling methods compared to the base handling method, sending the materials to landfill. While there is a considerable benefit to recycling of materials over sending them to landfill that credit can not be assigned to this life cycle since even in recycling there are emissions of greenhouse gasses.

Cardboard 121.5 gCO_2e

Cardboard waste is generated primarily from the delivery of hops which are delivered in one or two plastic bags in boxes. Each box carries about 44 lbs of hops and weighs 4.11 lbs each. The amount of cardboard associated with a keg of beer is 6.54 lbs for which the recycling accounts for 121.5 gCO_2e in emissions.

Paper Bags 3.3 gCO_2e

The paper bags used for delivery of the wheat are similar in material composition to the base fiber board used in cardboard boxes. There is no category for this material in the EPA report. To estimate the impacts the emissions for cardboard recycling will be used. For each keg of beer about 0.03 lbs of paper bags are used which when recycled result in 3.3 gCO_2e of emissions.

Plastic Bags < 0.0 gCO_2e

The plastic bags are a complex mixture of foil and plastic which are difficult to recycle. Currently they are sent with the waste to landfill. An insignificant amount of material is sent to landfill and will not be contribute to the carbon footprint.

Other Waste Materials

Waste from office operations was not included in the footprint. It is expected based on the NBB report that this will contribute very little to the overall footprint.

Downstream

Beer Delivery 2967.4 gCO_2e

Refrigeration 2963.9 gCO_2e

Each keg is used between 6 and 8 times per year. The keg is refrigerated while it contains beer in order to preserve the freshness of the product. During delivery and distribution the keg spends about 10 days at the distribution center and 7 days at the retailer before being emptied and returned for reuse. Using specifications for a new 600 square foot drive-in refrigeration system from Barr Refrigeration[29] and stacking filled kegs two high in the space gives an impact of 7.2 gCO_2e per hour of storage. Given a keg is refrigerated for approximately 240 hours at the distribution center accounting for 1743.5 gCO2e and 168 hours at the retail location accounting for 1,220.4 gCO2e the total for consumption of the beer is 2,963.9 gCO_2e.

Transportation 3.5 gCO_2e

Beer is delivered via truck to a distributor and then to a bar where it is served to the consumer. Once the keg is empty the delivery truck picks up the empty keg, returns it to the distributor and then to Goose Island. The average distance from Goose Island Brewery to the distributor is 7.5 miles and from the distributor to the bar is about an additional 7 miles. Round trip transportation is 14.5 miles at a weight of 172.2 lbs (Keg, beer and ¼ of a skid), and the return trip of 14.5 miles at a weight of 41.4 lbs (keg and skid only). Transportation results in emissions of 3.5 gCO_2e.

Discussion and Conclusions

Overall the carbon footprint of a keg of 312 beer is 25,226 gCO_2e with most of the impact in the grains (44%) and processing of the beer at Goose Island (42%) and a much smaller impact during distribution and consumption (12%).(see Figure 2) This is a little different from the usual impact assessment from the literature in that the production stage usually has little impact compared to the agricultural and use stages of the lifecycle. As expected from the literature the agricultural stage is a large user of energy but it also is responsible for considerable GHG emissions directly because of current soil management practices. (see Table 1 Barley Agriculture). Thirty one percent of the emissions from barley agriculture occur because of fertilizer and soil amendments and another 31% directly from soil emissions. Farming methods that reduce chemical fertilizer use and increase the sequestration of carbon in soil could significantly reduce the emissions from growing and harvesting grains.

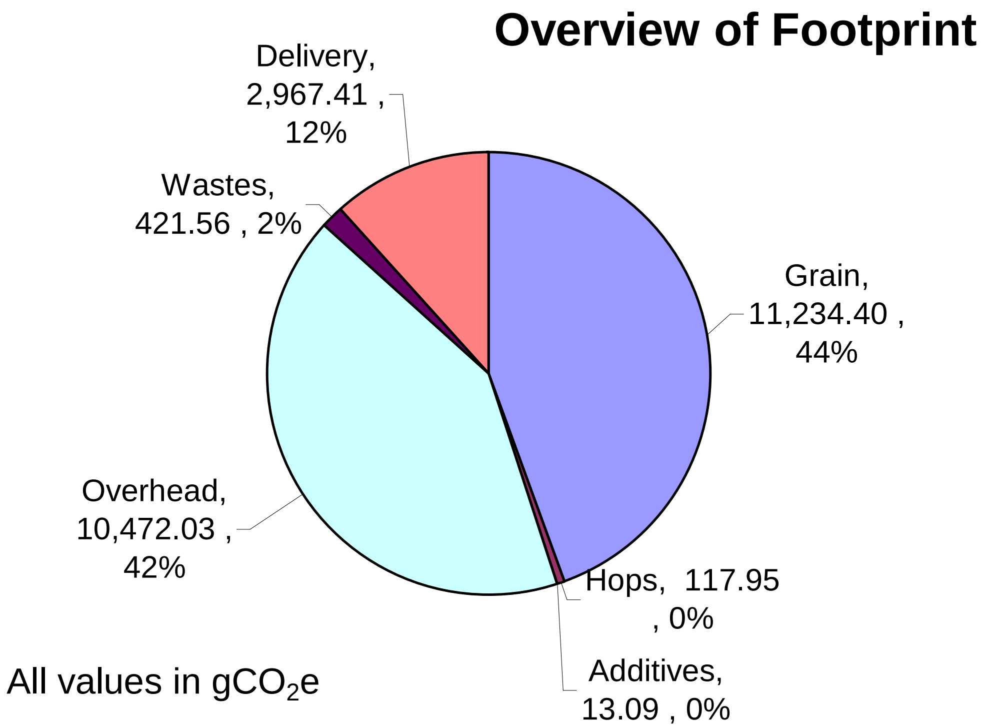


Figure 2 Life Cycle GHG emissions from a keg of 312 Beer.

The second largest impact area is the overhead or inputs into the process that are not measured at the batch level. These are inputs such as water or electricity which are measured on a site basis but used as needed for the processes in the brewery. As can be seen from Figure 3 the largest of the overhead impacts is the combustion of natural gas for steam in the boiler. Water, while used in very large volume, is not a strong contributor to the GHG emissions at
Goose Island. What is more interesting is the connection between reducing water use and gas used to heat that water. Most of the water used in the brewing of beer is heated to some extent, either for cleaning the tanks or during brewing. Goose Island uses 6 gallons of water for every gallon of beer produced. This ratio is about average for brewing operations world wide. Best in class breweries are reporting usages as low as 3 or 4 gallons of water for every gallon of product[30]. A significant reduction in water use has the beneficial impact of also reducing natural gas for the boilers. The second large source of carbon dioxide releases is the carbon dioxide gas used to both carbonate beer before kegging and to pressurize tanks during processing. Because this carbon dioxide

is of fossil origin any release contributes to the footprint. In an attempt to assess the source of CO_2 use an approximate value for the amount of carbon dioxide required for carbonation is taken from the NBB report. A change to nitrogen instead of carbon dioxide could reduce the operations emissions by approximately 567 gCO_2e.

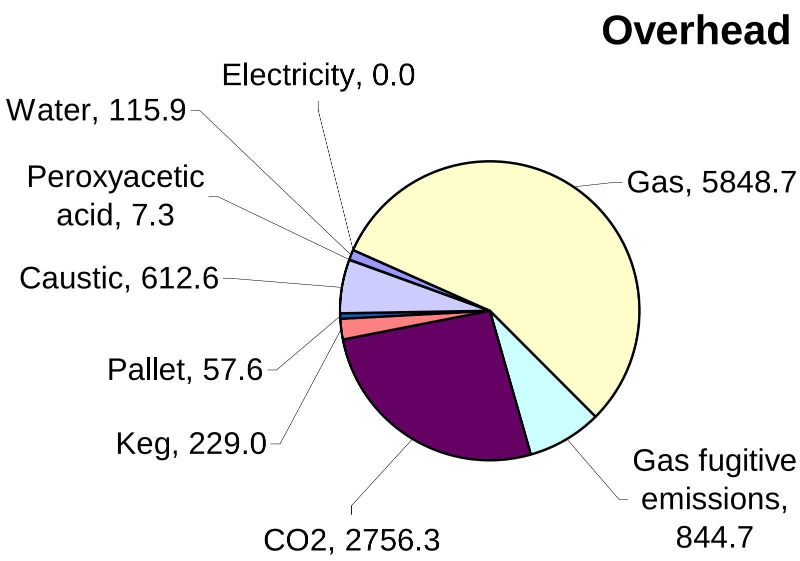


Figure 3 Impacts from Overhead Materials Use.

The third largest impact is the distribution stage and results from refrigeration taking up almost 2963 gCO_2e to the overall emissions. Because the distribution system is already fairly efficient there is probably limited room for improvement from minimizing the time spent under refrigeration. Even so every hour that a keg does not need to be refrigerated reduces the footprint by 7.26 gCO_2e. Further investigation into refrigeration systems and the relative performance of different systems at distributors might also find productive areas for emissions reduction through energy efficiency.

Unlike previous studies operations is a major source of emissions in Goose Island. After examination of the results of the study there are two areas that might be causing this difference. One is the large amount of gas being used for heating water, almost twice as much as was reported by NBB in their study. Another is the use of carbon dioxide for pressurizing tanks. NBB did not use CO_2 for this purpose and therefore did not have the considerable emissions associated with the carbon dioxide use.

Acknowledgement

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