Environmental performance of traditional beer production in a micro-brewery

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ABSTRACT

A life cycle assessment of traditional English beer brewed in a microbrewery has been made with blue water, cumulative energy and greenhouse gas emissions as used as measures of environmental performance. The boundary was delivery at the point of consumption. Cumulative energy demand was 4.4 MJ/l, greenhouse gas emissions were 0.38 kg CO_2e/l and blue water volumetric consumption was 3.4 l/l. The main burdens arise from raw material production (especially barley and then malt production), brewing operations, delivery and with waste management relatively small but not negligible. Other studies are not fully comparable, but these results are in the range reported for other beer types, countries and boundaries. Opportunities for environmental performance are limited by the small scale of a microbrewery. More detailed auditing is needed to establish what could be achieved. Existing water consumption appears to be relatively low. Solar generated electricity could be of benefit.

Keywords: Beer, Brewing, Micro-brewery, Water, Carbon footprint

1. Introduction

Beer (or ale) is the traditional alcoholic beverage in Britain. It is brewed in a different way from the globally widespread Pilsner type beer, ("lager" in the UK). Traditional beer (also known as "real ale") is brewed at a higher temperature than lager, is flavored with fertilized hops and is matured and served with live yeast in the casks (barrels), so that secondary fermentation provides the CO_2 when consumed. Lager is usually pasteurized, filtered and gassed with compressed CO_2. The LCA of lager has been studied in Estonia (Talve, 2001), Greece (Koroneos et al., 2003) and Italy (Cordella et al., 2008). The carbon footprint of a bottled ale was determined in the USA by Climate Conservancy (2009). Hotspots from these studies included crop production and processing, brewing and bottling. The UK is second largest brewer and consumer of beer in the EU, after Germany and the UK brews about 4,500 ML beer annually. The UK is the largest producer of cask beer in Europe. Brewing uses much energy and water. Parts of brewing's environmental performance have been studied in isolation in the UK, this is the first LCA and applies to cask rather than bottled beer.

2. Methods

Activity data were obtained from a local microbrewery on brewing operations, resources and fuel for distribution. Crop production was taken or derived from Williams et al. (2006). Energy and water requirements for malting came from the industry. Life cycle inventory (LCI) values for energy carriers and waste management came from the ELCD (2013). LCI values for minor ingredients came from Cranfield-derived data or were estimated by analogy. Co-product (spent brewers' grains) valuation was made by system expansion. The focus was energy use, greenhouse gas (GHG) emissions (GHGE) and water use.

2.1. Goal and Scope definition

The overall goal was to evaluate and determine the energy and water use and greenhouse gas (GHG) emissions (GHGE) as indicators of the environmental impact of the production of beer at a microbrewery and hence to assess its current environmental performance.

2.2. Functional Unit

The functional unit is one liter of "Shefford" beer (3.8% alcohol by volume), the main product, delivered to the point of consumption in pubs and to other distributers, in 2013. It is a draught beer often sold in pubs to the local community and other breweries. It is unpasteurised and unfiltered and so has also a short shelf life. Delivery was in casks that are cleaned and reused for many years, not bottles.

2.3. The system boundary

The product system includes all the life cycle steps from primary production (and associated inputs) through crop processing, brewing, waste management and delivery to outlets. Barley is the main ingredient, which is then malted (steeped, germinated and kilned) to produce malt. Hops are used for flavouring and are grown, harvested, dried and packaged. Brewing uses thermal and electrical energy, water and some minor inputs. Beer is matured in large tanks, casks are filled, the stored for about two weeks for the beer to mature and finally delivered. Wastewater from cleaning etc. is treated in the public sewerage system, spent hops and other wastes go to landfill and most spent brewers grains are mainly used for animal feed (with an estimated 5% sent to landfill).

2.4. Data sources and exclusion criteria

Primary data on the brewery activities, sourcing materials and beer delivery came from the brewers. These were derived from the records of six months brewing. An existing life cycle inventory (LCI) was used for barley (Williams et al., 2006) and one was extensively adapted for hops from oilseed rape (Williams et al., 2010). Energy and water use in malting came from the industry. LCI data for other minor ingredients came from analogues that were developed by Williams et al. (2006) or the literature. Energy use and waste management LCI data were taken from the European Life Cycle Database (ELCD 2012).

All GHGE were expressed on the 100 year basis using based on the IPPC (2007) coefficients. Water use was limited to the volumes of abstracted water used in malting, brewing and cleaning. Blue water used in energy production was not considered, but is thought to be much lower than these quantified sources.

Minor components that were likely to contribute less than 1% to any impact were excluded, e.g. yeast, which may be reused between brews. Fixed assets, like buildings, brewing equipment and casks were excluded.

2.5. Allocation methods

Economic allocation between barley grain and straw was as in Williams et al. (2010). Brewers' grains, when used as animal feed, were assumed to have the same feed value as the milling co-product, wheatfeed, on a dry matter basis, so that the avoided burdens method could be applied. No allocation was required if grains were sent to landfill.

3. Results

3.1. Resource use

The resource use in the production of one batch 1 l of Shefford Bitter beer is given in Table 1 and transport data in Table 2.

Table 1 Resource in the production of one batch (1475 l) of Shefford Bitter beer

Material input	Unit	Quantity
Malt	kg	0.15
Hops	kg	0.0020
Yeast	kg	0.0028
Water	l	3.39
Gypsum($CaSO_4$)	kg	0.00017
Calcium carbonate	kg	0.00017
Lactic acid	l	0.00037
Electricity	kWh	0.11348
Natural gas	kWh	0.12
Sodium hydroxide	l	0.00068

Table 2 Delivery distances and transport types of main raw materials

Product	Transport method	Distance, km
Malt	Bulk lorry	225
Hops	Bulk lorry	572
Hops	Large sea ship	15849
Ancillary material	Medium sized lorry	200
Packaging	Medium sized lorry	200

3.2. Burdens of production and delivery

The cumulative energy demand was 4.4 MJ/l, GHGE were 0.38 kg CO_2e/l and blue water volumetric consumption was 3.4 l/l.

The breakdown of burdens (Figure 2) shows that brewery activities itself dominates energy use (41%) with production of raw materials at 28%, transport at 26% and waste management at 5%. Almost all of the material production was for malt (including growing barley). Thermal energy and energy for temperature control were the most important aspects of the brewing stage. Most of the transport energy was for delivering the beer itself.

The distribution of GHGE was broadly similar with 28% from brewery activities, 30% from raw materials, 20% from transport, but waste management at 20%. Differences are mainly because of emissions of gases like nitrous oxide in agriculture and wastewater treatment.

Blue water use was mostly in the brewery activities (87%) and the rest from malting. The blue water in the brewery is split with 24% going into the beer itself and 63% as process and cleaning water.

In the brewery operations, most energy use is as electricity (73%) and thermal energy (natural gas) the remaining 27%. About 60% of the electricity is used for temperature control of the beer while it matures and awaits distribution.

In waste management, the treatment of brewery effluent in the local public sewerage system is the main process and has a magnitude of about eight times the solid waste management. Net solid waste management has a small negative impact owing to the use of brewers' grains for animal feed. If for practical or economic reasons, brewers' grains are sent to landfill, the cumulative energy use and GHGE increase by 4% and 5% respectively.

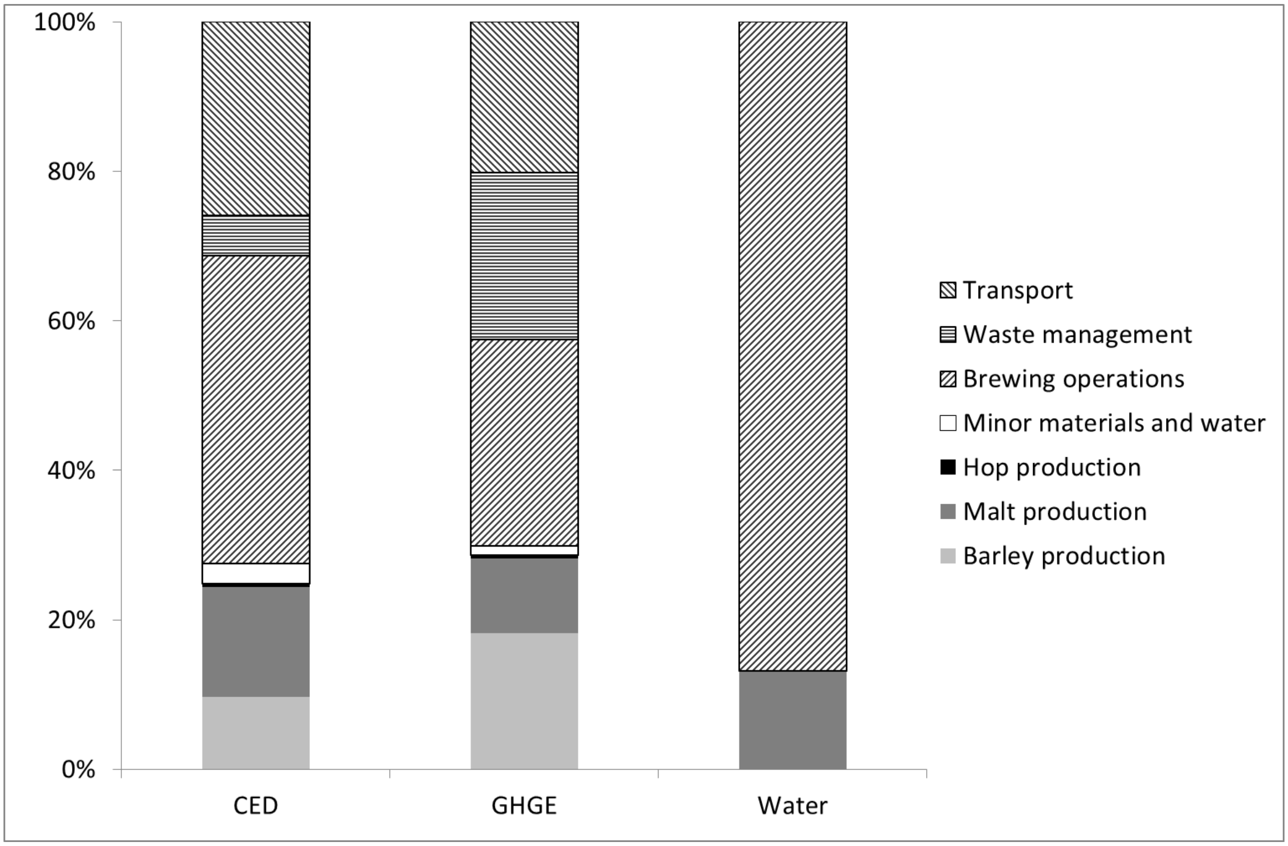

Figure 1 Breakdown of burdens of producing and delivering beer

3.3. Additional transport

Some beer gets sold on to other distributors or breweries to be sold in the free trade or as “guest beers”. Extra transport is needed for delivery. The additional burdens caused by this are linearly related to delivery distance. The increase in energy use and GHGE depends also on vehicle type and the effect is estimated in Table 3. Guest beers can readily be found over 500 km from the brewery, which would increase burdens in the range 12% to 40%, depend on vehicle type.

Table 3. Increase in energy use and GHGE at the point of consumption caused by increasing delivery distance by 100 km.

Vehicle type	Cumulative energy demand	GHGE
Bulk lorry transport	2.6%	2.1%
Medium sized lorry	5.8%	4.7%
Small delivery vehicle	8.7%	7.0%

4. Discussion

This is the first LCA of traditional British beer production. It provides an interesting contrast with that of continental styles of beer. It is also applied to a micro-brewery, which will use similar recipes for brewing as larger breweries, but other features will be different owing to economics of scale.

4.1. Opportunities for improvement

The three main stages of raw material production, brewing and delivery dominate most aspects of the burdens, although waste management has a larger relative role in GHGE. A small brewery such as this has little control over raw material production and waste management, especially of effluent. Control over brewing and temperature controlled beer storage in under brewery management control, but these tend to be more constrained in micro-breweries owing to their small scale.

Water use in brewing was relatively low at 3.4 l/l. The brewers of Europe (2002) reported that an efficient brewery uses 4 to 10 l/l and Goldammer (2008) noted that some brewers even uses more water, particularly the small breweries. In this case, there seems to be relatively little scope for improvement, but a more detailed audit could indicate possibilities.

A larger brewery would have its own effluent treatment plant, which if new, could minimize emissions and make positive use any upgrading technologies possible. While this brewery uses heat exchange, there may well be more opportunities for general heat recovery in a larger scale operation. Further, larger scale operations tend to incur lower heat losses. Larger breweries can also capture the CO_2 produced by fermentation for use in its own products, e.g. carbonated beers. This brewery produces no such products.

While the brewers' grains are usually used for animal feed, this does not always occur for practical reasons, such as the farmer having other priorities or not enough animals. An opportunity that is more open to larger brewers is using low grade heat to dry grains so that transport costs are reduced and the market becomes wider.

With a large amount of electricity being consumed, there could be opportunities for using the roof to mount solar panels hence to generate low emissions electricity.

The transport of beer is energetically intensive and this brewery is constrained by having one delivery vehicle for all goods. The delivery routes are not complex and need little optimizing. A larger operation can obtain environmental benefits from a delivery fleet such that loads and vehicles can be better matched. One distinct benefit of the delivery (and subsequent serving) system is that the weight of packaging overheads of cask beer (2.5%) is much smaller than for bottled beers (about 60%).

4.2. Data quality

The activity data was of high quality with good access to data from the brewery and a major maltster in England. The LCI data for processes such as waste management, from the ECLD, are of very high quality, although the effluent treatment data set is generic rather than specific.

A formal uncertainty analysis was not undertaken, but the overall uncertainty of the energy use and GHGE would be in the order of 10%, based on studies undertaken by Wiltshire *et al*., 2009.

4.3 Comparison with other studies

Other studies have inevitably used different boundaries, data sources, data inclusion and beer types, hence all comparisons require great caution.

Cordella et al. (2008) reported a range of energy consumption for Italian lager beer of 3.14 to 5.2 MJ/l, which is similar to the present study at 4.4 MJ/l. Talve (2001), in Latvia, only included electricity in energy use and found much lower value of 0.48 MJ/l. Koroneos et al (2003), in Greece, reported energy use of 0.69 MJ/l, of which beer production was only 6%. It seems to be a considerable underestimate or very efficient processing.

In contrast Koroneos et al (2003) reported GHGE of 754 kg CO_2e/l, compared with 0.38 kg CO_2e/l in the present study. Their value seems to be barely credible and some error seems likely, e.g. unit conversion, such that the real value was likely to be 0.75 kg CO_2e/l. Talve (2001) reported an order of magnitude lower GHGE of 0.065 kg CO_2e/l, but this appeared to omit features like N_2O and CH_4 emissions from agriculture, at least. The Climate Conservancy (2009) calculated carbon footprint for "Fat Tire Amber Ale" in the USA up to and including retail and use as 3.2 kg CO_2e/l. The study is very detailed and covers almost activities including business travel. Making an estimate of equivalent stages to those of the present study suggests GHGE of about 1 to 1.4 kg CO_2e/l and so three to four times higher than in the present study.

Our results seem to be in a reasonable range, but other studies have different locations, boundaries and features so that finding systematic differences is not really possible.

5. Conclusions

A life cycle assessment of traditional English beer brewed in a microbrewery has been made with blue water, cumulative energy and greenhouse gas emissions as used as measures of environmental performance. Cumulative energy demand was 4.4 MJ/l, GHGE were 0.38 kg CO_2e/l and blue water volumetric consumption was 3.4 l/l. This is up to delivery to the point of consumption.

The main burdens arise from raw material production, especially malted barley, brewing operations, delivery and with waste management relatively small but not negligible.

Other studies are not fully comparable, but these results are in the range reported for other beer types, countries and boundaries.

Opportunities for environmental performance are limited by the small scale of a microbrewery. More detailed auditing is needed to establish what could be achieved. Existing water consumption appears to be relatively low. Solar panels could help reduce the burdens of electricity use for temperature control.

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