**OUTPUT C: CARBON FOOTRPINT ASSESSMENT**

**THE KERNEL BREWERY**

**500ML BOTTLE OF PALE ALE**

****

**Report for the Kernel Brewery**

**CONTENTS**

**1. INTRODUCTION**

1.1 ALIGNMENT WITH INTERNATIONAL GUIDANCE

1.2 ABOUT THE BREWERY

1.3 FUNCTIONAL UNIT

1.4 INCLUSIONS

1.5 EXCLUSIONS

1.6 DATA

**2. BARLEY PRODUCTION**

2.1 BARLEY CULTIVATION

2.1.1 Allocation of barley cultivation emissions per functional unit

2.1.2 Emissions calculation for barley cultivation

2.2 BARLEY TRANSPORT

2.3 DISCUSSION

2.4 END NOTES

2.4.1 Data sources

2.4.2 Yield

2.4.3 Fertiliser

2.4.4 Pesticides

2.4.5 Water

2.4.6 Energy

2.4.7 Waste

2.4.8 Carbon removals from the atmosphere

2.4.9 Emissions calculation

**3. HOPS PRODUCTION**

3.1 CULTIVATION OF THE HOPS

3.1.1 Allocation of hops cultivation emissions per functional unit

3.1.2 Emissions calculation for hops cultivation

3.2 DRYING HOPS

3.2.1 Allocation and calculation for one functional unit

3.3 HOPS TRANSPORT

3.4 DISCUSSION

3.5 END NOTES

3.5.1 Data sources

3.5.2 Fertiliser

3.5.3 Pesticides

3.5.4 Water

3.5.5 Energy

3.5.6 Waste

3.5.7 Detailed emissions calculation

3.5.8 Hops transportation

**4. MALTING**

4.1 MALTING PROCESS

4.1.1 Allocation of malting emissions per functional unit

4.1.2 Emissions calculation for malting

4.2 MALT TRANSPORT

4.3 DISCUSSION

4.4 END NOTES

4.4.1 Energy use

4.4.2 Waste

4.4.3 Waste water

**5. PACKAGING**

5.1 PRIMARY PACKAGING (GLASS BOTTLES)

5.1.1 GLASS BOTTLE PRODUCTION

5.1.1.2 Allocation of emissions for 1 functional unit

5.1.1.3 Emissions calculation for glass bottles

5.1.1.4 Discussion

5.1.2 TRANSIT PACKAGING (GLASS BOTTLES TO BREWERY) PRODUCTION

5.1.2.1 Allocation for 1 functional unit

5.1.2.2 Emissions calculation

5.1.3 TRANSPORTING THE BOTTLES TO THE BREWERY

5.2 SECONDARY PACKAGING

5.2.1 SECONDARY PACKAGING PRODUCTION

5.2.1.1 Allocation for 1 functional unit

5.2.1.2 Emissions calculation

5.2.2 TRANSPORT FOR SECONDARY PACKAGING

5.3 DISTRIBUTION TRANSIT PACKAGING

5.3.1 DISTRIBUTION TRANSIT PACKAGING PRODUCTION

5.3.1.1 Allocation per functional unit

5.3.1.2 Emissions calculation

5.3.2 TRANSPORT OF THE TRANSIT PACKAGING FOR DISTRIBUTION

5.4 DISCUSSION

5.5 END NOTES

5.5.1 Glass bottle data sources

5.5.2 Glass bottle processes

5.5.3 Transit packaging for glass bottles

5.5.4 Secondary packaging emission factors

**6. BREWERY AND WAREHOUSING**

6.1 ALLOCATION PER FUNCTIONAL UNIT

6.2 EMISSIONS CALCULATION

6.3 DISCUSSION

6.4 END NOTES

6.4.1 Waste

6.4.1.1 By-products

6.4.1.2 Reuse

6.4.1.3 Landfill and recycling waste

**7. DISTRIBUTION TRANSPORT**

7.1 DATA AND METHODOLOGY

7.1.1 General assumptions

7.2 LONDON DISTRIBUTION EMISSIONS

7.3 REST OF UK DISTRIBUTION

7.3.1 Allocation per functional unit

7.3.2 Emissions calculation for rest of UK distribution

7.4 DISCUSSION

**8. RETAIL AND USE**

8.1 DATA AND METHODOLOGY

8.1.1 General assumptions

8.2 SHOPS (100 BOTTLES)

8.3 PUBS AND RESTAURANTS

8.4 DOMESTIC REFRIGERATION

8.4.1 Emissions calculation

8.5 DISCUSSION

**9. WASTE DISPOSAL**

9.1 DATA AND METHODOLOGY

9.2 ALLOCATION PER FUNCTIONAL UNIT

9.3 EMISSIONS CALCULATION

9.4 DISCUSSION

**10. CONCLUSION**

10.1 FINDINGS OF THE CARBON FOOTPRINT ASSESSMENT

10.1.1 Emissions hotspots

10.1.2 Emissions coldspots

10.2 HOW THE CARBON FOOTPRINT COULD BE REDUCED

10.2.1 Changing glass colour (approx 10kgCO2e/hl)

10.2.2 Reusable bottle (up to 10kgCO2e)

10.2.3 Renewable energy

10.2.4 Lower emission distribution transport

10.2.5 Other packaging options

10.2.6 Other types of barley

10.2.7 Conclusion

10.3 WHAT WILL NOT RESULT IN SIGNIFICANT EMISSIONS SAVINGS

10.3.1 Importing hops from Europe rather than the New World

10.4 FURTHER RESEARCH OPPORTUNITIES

**APPENDICES**

**APPENDIX A: De minimus sources**

**APPENDIX B: Transport emissions calculations**

**APPENDIX C: Emission factors**

**1. INTRODUCTION**

The aims of this carbon footprint assessment were to:

* Estimate the carbon footprint (climate change impact)[[1]](#footnote-1) of the whole life cycle (raw material extraction to waste disposal) of bottled Pale Ale produced by the Kernel brewery in 2013;
* Evaluate which stages or elements of the life cycle have the largest climate change impact;
* Where possible, compare the emissions to industry averages and other relevant published studies; and
* Identify how, and by how much, the largest impacts can be reduced.

The main body of this report contains 10 chapters. For simplicity, data analysis and descriptions of inputs and outputs are contained in chapter endnotes. Information to which many of the chapters refer is contained in appendices, which are at the end of the report.

**1.1 ALIGNMENT WITH INTERNATIONAL GUIDANCE**

This study was undertaken in accordance with PAS 2050 – an international standard for carbon footprinting (BSI 2011). As recommended in PAS 2050, supplementary industry guidance was used where applicable – in this case from the Beverage Industry Environmental Roundtable (BIER) (2014)[[2]](#footnote-2).

**1.2 ABOUT THE BREWERY**

The Kernel is a small, independent brewery in Bermondsey, London. The brewery produced 4,255 hectolitres of beer in 2013 in bottles and kegs. Just over a third of the brewery’s output in 2013 was Pale Ale, and approximately one third of the Pale Ale was bottled in 500ml bottles (with the remaining two thirds in kegs or different sized bottles).

**1.3 FUNCTIONAL UNIT**

The functional unit (FU) (i.e. what was assessed) chosen for this study by the brewery was one hectolitre of Pale Ale brewed in 2013 and sold in 500ml amber glass bottles. This equates to 200 x 500ml bottles of Pale Ale.

**1.4 INCLUSIONS**

The climate change impact of all life cycle stages of the beer were assessed in this report. The life cycle of the beer was broken down into 8 stages for this study, which are illustrated in figure 1 below.

**BARLEY PRODUCTION**

**HOPS PRODUCTION**

**MALTING**

**BREWERY AND WAREHOUSING**

**DISTRIBUTION**

**RETAIL AND USE**

**WASTE DISPOSAL**

**PACKAGING**

**PRODUCTION**

Figure 1: The flow of life cycle stages over the life of the beer in this study

Over the life of the beer:

* The barley is cultivated and transported to the malting company, where it is turned into malt and then transported to the brewery;
* The hops are cultivated in different countries around the world, then dried (some are also converted into pellets) and transported to the UK;
* Packaging materials are produced from raw materials (some also include recycled content) in various European countries, and then transported to the brewery;
* Beer is produced by the brewery (using malt, hops, yeast and sugar) and then bottled and stored in the brewery warehouse awaiting distribution;
* Some beer is distributed by distribution companies to London and the rest of the UK, and the remainder is sold direct from the brewery;
* After distribution, the beer is sold from shops, pubs and restaurants; and
* Finally, the packaging materials are disposed of at the end of the beer’s life – some are recycled and will be used to make new packaging materials, and the remainder are sent to landfill.

A process flow diagram for each life cycle stage can be found at the start of each life cycle chapter in this report (chapters 2-9).

**1.5 EXCLUSIONS**

**1.5.1 By-products**

In accordance with industry guidance, when ‘by-products’ (e.g. spent grain) are beneficially reused (e.g. by farmers for cattle feed), they have zero emissions once they have been separated from the main product (BIER 2014)*.* From that point on, the emissions are accounted for by the organisation that uses the by-products.

**1.5.2 De minimus sources**

According to carbon footprint guidance (BIER 2014; BSI 2011), to simplify the carbon footprint assessment, processes that are estimated to have a negligible impact on the overall footprint (less than 1% of emissions) can be excluded using the ‘1% rule’ (see appendix A for calculations). These are known as *de minimus sources*, and in this study they include:

* Insecticides, water and waste for barley cultivation;
* Various fuels for malting;
* Waste and sugar for brewing; and
* Fugitive refrigerants for retail and use.

**1.5.2 Where no information available**

Elements for which no data was available also had to be excluded. These include:

* Energy used to convert dried hops to pellets (chapter 3); and
* Solid waste, yeast and effluent treatment for the brewing stage (chapter 6).

**1.6 DATA**

Primary data (data collected first hand) was sought from all stages of the beer life cycle. Where primary data was provided, estimates are compared to industry averages.

Where primary data was not available, secondary data (data collected from other sources) was used.

Table 1 below summarises the type of data used for each stage.

|  |  |
| --- | --- |
| **Stage** | **Type of data** |
| Barley production | Secondary data |
| Hops production | Primary and secondary data |
| Malting | Primary data |
| Packaging | Secondary data |
| Brewery and warehousing | Primary data |
| Distribution | Primary data |
| Retail and use | Primary data |
| Waste disposal | Secondary data |

Table 1: Type of data used for each stage

A critical analysis of the data quality and assumptions used in this study is in section 10.1.3.

For simplicity, calculations made in this study have been rounded up to two decimal places, or nearest significant figure.

**2. BARLEY PRODUCTION (4.37kgCO2e)**

Malt, which is made from barley, is one of the principal ingredients of beer. Greenhouse gas (GHG) emissions from the malting stage are calculated in chapter 4. This chapter calculates the emissions from the barley production stage which are caused by:

* The cultivation of the barley (section 2.1); and
* The transportation of the barley from the farms to the malting company (section 2.2).

The carbon dioxide (CO2) emissions from the cultivation of barley arise from the use of energy for farm machinery, the provision of water, the production and transport of fertilisers and pesticides and the production of seeds for the barley (BIER 2014).

Nitrous oxide (N2O) emissions are also significant – N2O is a potent GHG, with a global warming potential almost 300 times that of CO2 over a 100 year time span (IPCC 2006). N2O is emitted during the production of nitrogen-based fertilisers, and from soil emissions that come about as a result of nitrogen fertiliser use (Garnett 2007).

Figure 2 below illustrates the process flow for the barley production stage, up until the arrival of the barley at the malting company.

**AGRICHEMICAL (FERTILISER/PESTICIDE) PRODUCTION**

AGRICULTURE – TILLAGE, SOWING, AGRICHEMICAL APPLICATION, HARVESTING

BY-PRODUCTS

WASTE

MALTING

**BARLEY TRANSPORT**



**SEED PRODUCTION**



Figure 2: Process flow for barley production

* **Light green = included processes**
* **Dark green = next stage, malting**
* **Grey = excluded processes**

Excluded from this stage are:

* By-products;
* *De minimus* sources – insecticides, water and waste (see Appendix A); and
* Carbon removals from the atmosphere (see section 2.4.8 for further details).

**2.1 BARLEY CULTIVATION (4.15gCO2e)**

Table 2 below summarises the inputs and outputs per hectare included in this study. Data could not be found from secondary sources that relate specifically to Maris Otter barley – a type of winter barley which is used in the Kernel’s Pale Ale. Data therefore either relates to ‘winter malting barley’ (preferred), or just ‘barley’.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **INPUTS / HECTARE** | **Quantity** | **Source** |  | **OUTPUTS / HECTARE** | **Quantity** | **Source** |
| **FERTILISERS** |  |  |  | Barley | 6.5kg | HGCA 2012 |
| Ammonium Nitrate | 85.2kg | National Fertiliser Survey (NFS) (Defra 2013a) |  | By-product (straw) | 1.17kg | BIER 2014 |
| Urea | 19.2kg | NFS (Defra 2013a) |  | Solid waste to landfill | 5kg | Simply Hops |
| UAN | 15.6 kg | NFS (Defra 2013a) |  |  |  |  |
| Compound nitrogen fertiliser (N:P:K) | 9 kg | NFS (Defra 2013a) |  |  |  |  |
| Phosphate fertiliser | 30 kg | NFS (Defra 2013a) |  |  |  |  |
| Potash Fertiliser (Muriate of Potash) | 41 kg | NFS (Defra 2013a) |  |  |  |  |
| Sulphur fertiliser (Ammonium Sulphate) | 25 kg | NFS (Defra 2013a) |  |  |  |  |
| **PESTICIDES** |  |  |  |  |  |  |
| Herbicides | 1.53 kg | National Pesticide Survey (NPS) (Defra 2013b) |  |  |  |  |
| Insecticides | 0.015 kg | NPS (Defra 2013b) |  |  |  |  |
| Fungicides | 0.765 kg | NPS (Defra 2013b) |  |  |  |  |
| **ENERGY / WATER** |  |  |  |  |  |  |
| Red diesel | 69kg | BIER 2014 |  |  |  |  |
| LPG | 3.9 litre | Farm Energy Survey 2013d |  |  |  |  |
| Kerosene | 11.8 litre | Farm Energy Survey 2013d |  |  |  |  |
| Electricity | 115.5 kWh | Farm Energy Survey 2013d |  |  |  |  |

Table 2: Inputs and outputs for barley cultivation per hectare

* Black text highlights included elements
* Grey text highlights excluded elements
* Green text highlights elements that are calculated in other sections

In line with industry guidance (BIER 2014), emissions from the production of seeds are accounted for using an emission factor that is applied to the total cultivation emissions (see calculation in section 2.4.9).

Further details of the inputs and outputs, and analysis of the sources of secondary data, are discussed in more detail in the end notes (section 2.4) of this chapter, as shown in table 3 below.

|  |  |
| --- | --- |
| **Section number** | **Section title** |
| 2.4.1 | Data sources |
| 2.4.2 | Yield |
| 2.4.3 | Fertilisers   * Production emissions * N2O emissions from soils |
| 2.4.4 | Pesticides |
| 2.4.5 | Water |
| 2.4.6 | Energy |
| 2.4.7 | Waste |
| 2.4.8 | Carbon removals from the atmosphere |

Table 3: End note sections

**2.1.1 Allocation of barley cultivation emissions per functional unit**

21.14kg of malt is used to produce each functional unit of Pale Ale. According to the malting company, 1 tonne of barley is used to make 830kg of malt. Using this ratio of barley to malt, one functional unit would require 25.47kg barley.

|  |  |
| --- | --- |
| **Barley (kg)** | **Malt (kg)** |
| 1,000 | 830 |
| 25.47 | 21.14 |

Table 4: Calculation of the amount of barley required to produce enough malt to make 1hl of beer

If the yield is 6.5 tonnes / hectare (HGCA 2013), then 25.47kg barley would require 0.0039 hectares.

|  |  |  |
| --- | --- | --- |
| **Quantity barley (kg/FU)** | **Yield (kg/ha)** | **ha/FU** |
| 25.47 | 6,500 | 0.0039 |

Table 5: Calculation of the number of hectares (ha) required to produce enough barley for 1 functional unit (FU)

**2.1.2 Emissions calculation for barley cultivation**

The full calculations of emissions per hectare for barley cultivation are shown in this chapter’s end notes in section 2.4.9. Emissions per hectare were multiplied by the number of hectares of barley required per hectolitre of Pale Ale (0.0039), to give the emissions per functional unit. The emissions per functional unit are summarised by input type in table 6 below.

|  |  |
| --- | --- |
|  | **Emissions (kgCO2e/FU)** |
| Fertiliser production | 1.21 |
| Pesticide production | 0.05 |
| N2O emissions from soils | 1.43 |
| Energy | 1.27 |
| Seed production | 0.20 |
| **TOTAL** | **4.15** |

Table 6: Summary of emissions for barley cultivation per functional unit (FU)

**2.2 BARLEY TRANSPORT (0.22kgCO2e)**

The barley is transported by heavy goods vehicle (HGV) from the farms to the malting company. A tonne.km (the distance travelled multiplied by the weight of the freight transported) emission factor for HGVs over 17 tonnes is used for estimating the emissions from transporting the barley (DECC/Defra 2012). Emissions were therefore estimated by calculating the emissions from transporting the total amount of barley required for one functional unit (25.47kg) the average distance from the farms to the malting company (40.87km) (provided by the barley supplier, Adams and Howling, personal communication, 2014).

Transport emissions calculations are shown in appendix B and are estimated to be 0.22kgCO2e per functional unit.

**2.3 DISCUSSION**

Figure 3 shows the breakdown of emissions from the barley production stage.

Figure 3: Breakdown of emissions from barley production stage

As shown in figure 3 above, energy used in the cultivation stage is responsible for nearly one third of the emissions from the production of the barley. However the most significant contributor to the emissions from the barley production stage is the fertiliser, which is responsible for approximately two thirds of the emissions from this stage (including the N2O emissions from soils as a result of fertiliser use as well as the fertiliser production emissions).

**2.4 END NOTES**

**2.4.1 Data sources**

Five of the thirty farms that produce the barley were asked to provide estimates of inputs and outputs for the cultivation of barley, but unfortunately none were able to supply the data. Secondary data specific to Maris Otter barley was not available (with the exception of a yield estimate). Hence, a search for secondary data was commenced. Where possible, data for malting barley was sought (rather than non-malting barley[[3]](#footnote-3)). Where this was not possible, winter barley was used rather than generic barley data[[4]](#footnote-4). National statistics were used where available. Where possible, data selected for use in this study was cross-checked with other carbon footprint reports and agricultural industry reports.

The barley data sources that were used in this study, along with an analysis of their transparency and relevance to this study, are listed in table 7 below.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Source** | **Source type** | **Transparent?** | **Peer reviewed?** | **Relevance** | | | |
| **Malting winter barley** | **Winter barley** | | **Barley** |
| Yield | HGCA (2012) | Industry report | Yes | Unclear |  | ✔ | |  |
| Fertiliser use | Defra (2013a) | National statistic | Yes | Yes | ✔ |  | |  |
| Pesticide use | Defra (2013b) | National statistic | Yes | Yes |  | ✔ | |  |
| Water | HGCA (2013) | Industry report | Yes | Yes |  |  | | ✔ |
| Energy (Diesel) | BIER (2014) | Industry guidance | No | No |  |  | | ✔ |
| Energy (other) | Defra Farm Energy Survey (Defra 2013c) | Government report | Yes | Yes |  |  | | ✔ |
| Waste | Simply Hops (Personal communication) | Company survey | No | No | Data for cultivation of hops | | | |
| Water | HGCA 2013 | Industry report | Yes | Yes |  |  | ✔ | |
| Seed production | BIER (2014) | Industry guidance | Yes | No |  |  | ✔ | |

Table 7: Analysis of data sources used in this study for the cultivation of the barley

The majority of the barley used by the brewery in 2013 would be from the summer 2012 harvest. Where available, cultivation data and emissions factors from 2012 are therefore used in this stage.

**2.4.2 Yield**

There are several reports and carbon calculators that contain estimates for barley yields (HGCA 2012; Muntons 2013). Data from the HGCA Harvest report (2012) (estimate of 6.5-6.7tonnes/hectare (ha)) was used because, unlike the other two reports, it relates specifically to winter barley.

Since the data is not specifically for malting winter barley, and malting barley tends to have a lower yield than non-malting barley, the yield for malting winter barley is likely to be at the lower end of the range of the yield estimate. 6.5 tonnes/ hectare was therefore used as the yield for this study.

This is within the bounds of the yield range suggested in an article on Maris Otter barley in the Farmers Guardian (Jones 2010), which suggests that yields tend to be between 6 and 7 tonnes/ha. Due to the large range in potential yields for the Maris Otter barley, an uncertainty analysis was performed at the end of this report (section 10.2.5) to assess what impact the yield can have on the emissions from the cultivation of the barley stage.

**2.4.3 Fertiliser**

There are three ways in which emissions are produced as a result of nitrogen fertilisers for the barley cultivation stage:

* The production and transportation of the fertilisers to the farm;
* The energy required to power the machinery that spreads the fertiliser on the ground (accounted for in the energy section 2.4.6); and
* The nitrous oxide (N2O) emissions that result from the application of nitrogen fertiliser to soils (Garnett 2007).

*Fertiliser use*

Estimated quantities of each type of fertiliser applied per hectare (in table 8) were taken from The British Survey of Fertiliser Practice 2012[[5]](#footnote-5) (Defra 2013a).

*Different types of nitrogen fertiliser*

The British Survey of Fertiliser Practice 2012 (Defra 2013a) found that an average of 129kg/ha of nitrogen fertilisers was used on malting winter barley in 2012. Different nitrogen fertilisers contain different quantities of nitrogen, and therefore have different emission factors. The percentage of the fertiliser used by nitrogen fertiliser type was therefore calculated, and is shown in figure 4 below.

Figure 4: Nitrogen fertiliser use (based on figures from table B1.3 in Defra 2013a)

Using the percentages in figure 4 above, estimates for the amounts of each nitrogen fertiliser type used were calculated in table 8 below.

|  |  |  |
| --- | --- | --- |
|  | **% of total fertiliser use (Defra 2013a)** | **Total (kg/ha)** |
| Ammonium Nitrate | 66 | 85.14 |
| Urea | 15 | 19.35 |
| UAN | 12 | 15.48 |
| Compound | 7 | 9.03 |
| **Total fertiliser use** | **100** | **129** |

Table 8: Calculation of amounts of each fertiliser type

*Fertiliser – emission factors for production emissions of different fertilisers*

Several GHGs (CO2, N20 and CH4) are emitted from the extraction of resources, transport of raw materials and products, and the production of the fertilisers. Different fertilisers have different production emissions (Wood and Cowie 2004).

Emission factors can be either per kilo (kg) of fertiliser, or in the case of nitrogen fertilisers, per kg of nitrogen (N) (e.g. Ammonium Nitrate is typically 34% N). Because the quantities of nutrients can vary depending on the brand, and it is not known which brands were used, emission factors are used per kg of product in this study. However it should be noted that accurately calculating emissions from fertiliser production can be problematic, due to the large variety of types and manufacturers of fertilisers (Wood and Cowie 2004).

An analysis of emission factor sources used in this study is shown in table 9 below.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Source** | **Year** | **Source type** | **Transparency** | **Emissions** | | | **Transport to manuf** | **Transport to fields** |
|  |  |  |  | **CO2** | **N2O** | **CH4** |  |  |
| Davis and Haglund | 1999 | Masters Thesis | Yes | ✔ | ✔ | ✔ | ✔ | x |
| Elsayed et al. | 2003 | Report | Partial | ✔ | ✔ | ✔ | X | x |
| Patyk and Reinhardt | 1996 | Conference proceedings | Partial | ✔ | ✔ | ✔ | ✔ | ✔ |
| Patyk | 1996 | Conference proceedings | Partial | ✔ | ✔ | ✔ | ✔ | ✔ |
| Kongshaug | 1998 | Conference proceedings | Partial | ✔ | ✔ | x | X | x |
| West and Marland | 2001 | Journal article | Partial | ✔ | X | x | ✔ | ✔ |

Table 9: Analysis of data sources of fertiliser production emissions (from Wood and Cowie 2004)

Although emission factors from Kongshaug (1998) are regularly quoted in studies and calculators (e.g. HGCA carbon calculator), they do not include methane (CH4) emissions or transport emissions (although Wood and Cowie (2004) note that transport emissions are fairly insignificant, apart from with phosphate fertilisers). Other studies are therefore used instead where possible.

*Nitrous Oxide (N2O) emissions from soils*

When nitrogen is added to agricultural soils through the use of synthetic fertilisers, direct emissions are produced from the application of the fertiliser, and indirect emissions are produced from nitrogen volatisation and leaching (IPCC 2006).

In order to calculate the emissions from soils for this study, the amount of nitrogen contained in each fertiliser (taken from Wood and Cowie (2004)) was multiplied by the quantity of nitrogen fertiliser applied to each hectare, to give the quantity of nitrogen applied to each hectare (shown in table 10). This was then multiplied by IPCC emission factors (2006) in table 11, to give the total N2O emissions. The N2O emissions were then multiplied by the global warming potential (GWP) of nitrogen (298), to give the CO2e emissions per hectare (see table 11). See appendix C for an explanation of emission factors.

|  |  |  |  |
| --- | --- | --- | --- |
| **FERTILISER TYPE** | **CALCULATION OF NITROGEN (N) APPLIED** | | |
| **% N (Wood and Cowie 2004)** | **Quantity fertiliser applied (kg/ha)** | **Quantity N applied (kgN/ha)** |
| Ammonium nitrate | 35% | 85.2 | 29.82 |
| UAN | 32% | 15.6 | 4.992 |
| Urea | 46% | 19.2 | 8.832 |
| Compound | 11% | 9 | 0.99 |

Table 10: Calculation of N applied by each fertiliser

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **FERTILISER TYPE** |  | **CALCUATION N2O EMISSIONS** | | | | **GWP of N** | **EMISSIONS (kgCO2e)** |
| **Quantity N applied (kgN/ha)** | **EF - Direct N2O emissions** | **EF – leaching** | **EF - volatisation** | **Total N2O emissions** |
| Ammonium nitrate | 29.82 | 0.01 | 0.01 | 0.0075 | 0.82 | 298 | 244.37 |
| UAN | 4.99 | 0.01 | 0.01 | 0.0075 | 0.134 | 298 | 40.91 |
| Urea | 8.83 | 0.01 | 0.01 | 0.0075 | 0.24 | 298 | 72.38 |
| Compound | 0.99 | 0.01 | 0.01 | 0.0075 | 0.03 | 298 | 8.11 |
|  |  |  |  |  |  | **TOTAL** | **365.77** |

Table 11: Calculation of N2O emissions (using emissions factors (EF) from IPCC (2006))

**2.4.4 Pesticides**

A range of pesticides (mostly herbicides, fungicides and insecticides) are applied routinely to barley fields (Defra 2013b). According to a national pesticide survey (Defra 2013b), 3.06kg/ha of pesticides were applied to winter barley in the UK in 2012 (see table 12 below).

|  |  |
| --- | --- |
| Winter barley in UK in 2012 (hectares) | 348,666 |
| Pesticide applied in 2012 (tonnes) | 1,177.17 |
| Average application (kg/ha) | 3.06 |

Table 12: Calculations for average application of pesticide to barley, using data from Defra (2013b)

The use of insecticides is responsible for less than 1% of the overall carbon footprint (see appendix A). It is therefore classified as a *de minimus* source and is excluded from the carbon footprint calculation.

*Pesticide production emissions*

There are few detailed studies of pesticide production emissions. A report by West and Marland (2001) investigated carbon dioxide emissions and energy use from production and post-production of pesticides in the US in 1996. Lal (2004) also gives estimates for carbon emissions from production, formulation and packaging of the pesticides based on various studies from different countries with large ranges of uncertainty (see table 13 below). However, given the negligible contribution of pesticide emissions to the overall footprint of the life of the beer (0.05kgCO2e of the 71.27kgCO2e emissions), an uncertainty analysis was not performed. An average was taken of the emission factors from the two studies.

|  |  |  |  |
| --- | --- | --- | --- |
| **Pesticide type** | **Emission Factor** | | |
| **Lal (2004)** | **West and Marland (2001)** | **Average** |
| Herbicide | 6.3 (+/- 2.7) | 4.7024 | 5.50 |
| Fungicide | 3.9 (+/- 2.2) | 5.1775 | 4.54 |

Table 13: Emission factors for pesticides

**2.4.5 Water**

UK barley has a very low water footprint – less than 500m3/tonne, which is less than France, Germany, USA and the global average (Mekonen and Hoekstra 2010).

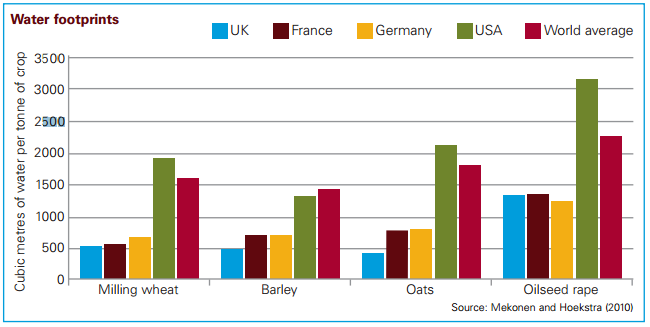


Figure 5: Comparison of water footprints for barley (Mekonen and Hoekstra 2010)

Cereal crops in the UK are largely rain-fed, and typically less than 0.3% of cereals crops receive irrigation in the UK. The amount of irrigation used varies year on year, depending on the rainfall (HGCA 2013).

0.0039 hectares is required to produce the barley required for one hectolitre of Kernel Pale Ale (see section 2.1.1). If 0.3% of the crops require irrigation, that would be 0.000017 hectares.

|  |  |
| --- | --- |
| 0.0039 | Hectare of barley to make one hectolitre of beer |
| 0.3% | % of cereal crops requiring irrigation |
| 0.000017 | Hectares that require watering per functional unit |

Table 14: Calculation of number of hectares requiring water for one functional unit (FU)

As shown in appendix A, the water emissions for 0.000017 hectares of barley are less than 1% of the overall footprint, and are therefore excluded.

**2.4.6 Energy**

Several agricultural practices are carbon intensive due to the fuel that it is consumed, in particular ploughing and harvesting (Lal 2004). The industry guidance (BIER 2014) estimates 69 kg diesel / hectare. Other fuels that are not included in the industry guidance are also used in agriculture. A survey on energy use in farming (Defra 2013c) provides estimates for energy inputs in agriculture for use of other fuels, and they were included in this study

**2.4.7 Waste**

It is estimated that 18% of harvested barley are by-products, such as straw, which are reused by other organisations within the agricultural industry and therefore have zero emissions (see section 1.5).

Emissions from landfill waste are shown to be negligible for barley cultivation and are therefore excluded (see appendix A).

**2.4.8 Carbon removals from the atmosphere**

The carbon uptake of the barley during cultivation approximately cancels out the carbon dioxide that is emitted during the fermentation of the beer (Garnett 2007). Carbon footprint guidance (BSI 2011) states that carbon removals from the atmosphere can be excluded for food and feed products, so they were not calculated in this study.

**2.4.9 Barley cultivation emissions calculation**

Detailed calculations of the emissions from barley cultivation are shown in table 15 below.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **ESTIMATE** | | **EMISSION FACTOR** | | | **EMISSIONS** | |
| **Quantity** | **Unit** | **Emission factor** | **Source** | **GWP** | **Per hectare (kgCO2e/ha)** | **Per hl (kgCO2e/hl)** |
| **FERTILISER PRODUCTION** | | | | | | | |
| Ammonium Nitrate | 85.2 | kg/ha | 2.3800 | Average from D&H (1999) and Elsayed (2003) (kgCO2e/kg product) |  | 202.7760 | 0.79 |
| Urea | 19.2 | kg/ha | 1.8487 | D&H (1999) |  | 35.4950 | 0.14 |
| UAN | 15.6 | kg/ha | 1.8441 | D&H (1999) |  | 28.7680 | 0.11 |
| Compound fertiliser (N:P:K) | 9 | kg/ha | 1.2107 | D&H (1999) |  | 10.8963 | 0.04 |
| Phosphate fertiliser | 30 | kg/ha | 0.5116 | Average D&H (1999), P&R (1996) and Patyk (1996) |  | 15.3471 | 0.06 |
| Muriate of potash | 41 | kg/ha | 0.2000 | Konghaug 1998 |  | 8.2000 | 0.03 |
| Ammonium sulphate | 25 | kg/ha | 0.3400 | Konghaug 1998 |  | 8.5000 | 0.03 |
| **N2O EMISSIONS FROM SOILS** | | | | | | | |
| Direct emissions | 44.634 | kgN/ha | 0.0100 | IPPC 2007 | 298 | 133.0093 | 0.52 |
| Volatisation | 44.634 | kgN/ha | 0.0100 | IPPC 2007 | 298 | 133.0093 | 0.52 |
| Leaching | 44.634 | kgN/ha | 0.0075 | IPCC 2007 | 298 | 99.7570 | 0.39 |
| **PESTICIDES** | | | | | | | |
| Herbicides | 1.53 | kg/ha | 5.5012 | West and Marland 2001; Lal 2004 |  | 8.4168 | 0.03 |
| Fungicides | 0.765 | kg/ha | 4.5388 | West and Marland 2001; Lal 2004 |  | 3.4722 | 0.01 |
| **ENERGY** | | | | | | | |
| Diesel | 69 | kg/ha | 3.4270 | DECC/Defra 2012 |  | 236.4630 | 0.92 |
| LPG | 3.9 | litre/ha | 1.5326 | DECC/Defra 2012 |  | 5.9771 | 0.02 |
| Kerosene (burning oil) | 11.8 | litre/ha | 2.5443 | DECC/Defra 2012 |  | 30.0227 | 0.12 |
| Electricity kWh/ha | 115.5 | kWh/ha | 0.4600 | DECC/Defra 2012 |  | 53.1323 | 0.21 |
| **OTHER** | | | | | | | |
| Seed production |  |  | 1.05 \* total emissions | BIER 2014 |  | 50.6621 | 0.20 |
| **TOTAL FOOTPRINT FOR BARLEY CULTIVATION** | | | | | | **1063.9043** | **4.15** |

Table 15: Calculations of emissions per functional unit for barley cultivation

**3. HOPS PRODUCTION (0.77kgCO2e)**

The majority of the hops used to make the Kernel’s Pale Ale are imported from the New World, where the soil and climate give the hops certain flavours (such as citrus and pine) that are favoured by the brewery. Typically hops from the USA, New Zealand, Australia and Germany are used to brew the Pale Ale. The brewery uses hops in two forms: dried and baled form, and also hops that are in pellet form (they are powdered and compressed into pellets).

In another carbon footprint study, the cultivation of hops has been shown to be responsible for a negligible amount of emissions in comparison to the overall emissions for a beer – less than 0.1% (TCC 2008) – partly due to the fact that the amount of hops is by mass less than 1% of the dry ingredients. Using the 1% rule, the cultivation of hops could therefore be excluded from this study. However, given the distance that the hops must travel to be imported to the UK, a decision was made to include them, to evaluate whether importing hops from the New World has a significant impact on the overall footprint[[6]](#footnote-6).

Emissions from this stage are caused by the:

* Cultivation of the hops (section 3.1);
* Drying of the hops (section 3.2); and
* Transportation of the hops to the brewery (section 3.2).

Figure 6 below illustrates the process flow for the hop production stage, up until the arrival of the hops at the brewery.

**AGRICHEMICAL (FERTILISER/PESTICIDE) PRODUCTION**

**AGRICULTURE – TILLAGE, AGRICHEMICAL APPLICATION, HARVESTING ETC...**

**HOPS DRYING**

BY-PRODUCTS

WASTE

BREWERY

**HOPS TRANSPORT**



**CONVERSION TO PELLETS**



Figure 6: Process flow for hops production stage

* **Green = included processes**
* **Grey = excluded processes**
* **Blue = next life cycle stage, brewery and warehousing**

Excluded from this stage are:

* Data for the energy required to convert the dried hops to pellets which was unavailable (however some of the energy used to convert the hops to pellets is likely to be offset by the lower transportation emissions due to their smaller size per kilo (Garnett 2007));
* By-products; and
* Waste.

**3.1 CULTIVATION OF THE HOPS (0.47kgCO2e)**

Quantities of inputs and outputs per hectare were supplied by Simply Hops (one of the Kernel’s suppliers) for the hops from the USA. These are shown in table 16 below. Simply Hops also provided estimates of yields for the USA hops. Data was unavailable for the other countries.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **INPUTS / HECTARE** | **Quantity** |  | **OUTPUTS / HECTARE** | **Quantity** |
| **FERTILISERS** |  |  | Hop bales | 1000kg |
| Nitrogen fertiliser | 100kg |  | Hop pellets | 965kg |
| Phosphorous fertiliser | 50kg |  | By-products | 30kg |
| Potassium Fertiliser | 100kg |  | Recycled waste |
| **PESTICIDES** | |  | Reused waste |
| Herbicide | 1.5kg |  | Landfill waste | 5kg |
| Insecticide | 1kg |  |  |  |
| Fungicide | 1kg |  |  |  |
| **ENERGY / WATER** | |  |  |  |
| Water | 30532hl |  |  |  |
| Diesel | 64.2kg |  |  |  |

Table 16: Inputs and outputs per hectare for hops (all quantities provided by Simply Hops)

* Black text highlights included elements
* Grey text highlights excluded elements
* Green text highlights elements that are calculated in other sections

Further details of the inputs and outputs, and an analysis of the sources of secondary data, are in this chapter’s end notes (section 3.5), as shown in table 17 below.

|  |  |
| --- | --- |
| 3.5.1 | Data sources |
| 3.5.2 | Fertiliser   * Production emissions * N2O emissions from soils |
| 3.5.3 | Pesticide |
| 3.5.4 | Water |
| 3.5.5 | Energy |
| 3.5.6 | Waste |

Table 17: Chapter end note sections

**3.1.1 Allocation of hops cultivation emissions per functional unit**

Average quantities of baled and pellet hops used per functional unit were provided by the brewery.

|  |  |
| --- | --- |
| **Baled hops (kg/FU)** | **Pellet hops (kg/FU)** |
| 0.417 | 0.417 |

Table 18: Amounts of hops per functional unit (FU) (figures supplied by Kernel Brewery)

Due to the compressing and powdering of the pellet hops after the hops have been dried (which further reduces the weight compared to just drying the hops), the weight of pellet hops produced from each hectare (i.e. yield) is lower than the weight of dried hops produced per hectare (1,793 kg/ha for dried hops compared to 1,730kg/ha for pellet hops). In order to calculate the cultivation emissions of certain amounts of dried and pellet hops, dried hops and pellet hops yields per hectare were required. These were provided by Simply Hops for the USA hops.

**3.1.2 Emissions calculation for hops cultivation**

Detailed calculations per hectare are shown in section 3.5.7 in the chapter’s end notes and are summarised in table 19 below for the USA hops.

|  |  |
| --- | --- |
|  | **EMISSIONS (kgCO2e/ha)** |
| Fertiliser production | 255.81 |
| N20 emissions from soils | 286.83 |
| Pesticide production | 17.89 |
| Energy | 436.13 |
| **TOTAL** | **996.65** |

Table 19: Summary of emissions per hectare from hops cultivation from section 3.5.7

The emissions per functional unit for the baled hops and pellet hops were calculated in table 20 below, using total emissions per hectare from table 19 above, and specific yields per hectare (provided by Simply Hops) for bales (1793kg) and pellets (1730kg).

|  |  |
| --- | --- |
| **BALES** | |
| Emissions (kgCO2e/ha) | 996.65 |
| Dry weight yield (kg/ha) | 1793 |
| Allocation (kg/FU) | 0.42 |
| Hectare / FU | 0.0002 |
| **Emissions/FU (kgCO2e)** | **0.23** |
| **PELLETS** | |
| Emissions/ha (kgCO2e/ha) | 996.65 |
| Dry pellet yield (kg/ha) | 1730 |
| Allocation (kg/FU) | 0.42 |
| Hectare/FU | 0.0002 |
| **Emissions/FU (kgCO2e)** | **0.24** |
| **TOTAL HOPS EMISSIONS/FU (kgCO2e)** | **0.47** |

Table 20: Calculation of total emissions from hop cultivation per functional unit (FU)

**3.2 DRYING HOPS (0.04kgCO2e)**

Estimates for energy use for drying hops were taken from the carbon footprint study of a beer in the USA using hops from the Yakima region, which is where the USA hops that the Kernel brewery uses are cultivated (TCC 2008).

**3.2.1 Allocation and calculation for one functional unit**

It is estimated that 0.9gCO2e is emitted from drying the amount of hops required for approximately 2.05 litres of beer (TCC 2008). Using this ratio of emissions from drying to quantity of beer, for 1 hectolitre of beer (100 litres) the emissions would be 0.04kgCO2e, as shown in table 21 below.

|  |  |
| --- | --- |
| **Emissions (gCO2e)** | **Per** |
| 0.9 | 2.05 l beer |
| 0.04 | 1 hl beer |

Table 21: Estimation of emissions per functional unit (hl) from drying hops based on TCC (2008).

It should be noted that this does not take into consideration differences in weights of hops used per hectolitre between the breweries, because that information was not available.

**3.3 HOPS TRANSPORT (0.26kgCO2e)**

The weight of hops imported from each country per functional unit and their associated transport emission are summarised in table 22 below. Emission factors and assumptions used are discussed in end note section 3.5.4. Detailed calculations of the emissions from transportation are shown in appendix B.

|  |  |  |
| --- | --- | --- |
| **Country** | **Weight hops (kg/FU)** | **Transport emissions (kgCO2e/FU)** |
| USA | 0.61 | 0.23 |
| Australia | 0.12 | 0.01 |
| Germany | 0.04 | 0.01 |
| New Zealand | 0.07 | 0.01 |
| **TOTAL** | **0.83** | **0.26** |

Table 22: Summary of transport emissions from importing the hops from each country per functional unit (FU) from Appendix B

**3.4 DISCUSSION**

The breakdown of emissions for hops production are summarised in table 23 below and illustrated in figure 7.

|  |  |
| --- | --- |
|  | **Emissions (kgCO2e/FU)** |
| Cultivation of hops | 0.47 |
| Drying of hops | 0.04 |
| Transportation of hops | 0.26 |
| **Total** | **0.77** |

Table 23: Summary of emissions from hops production stage

Figure 7: Breakdown of hops production emissions

The cultivation of the hops is responsible for the largest share of the emissions from hops production, followed by the hops transport, which is responsible for 33% of the hops production emissions. However, hops production is just over 1% of the overall footprint of the beer (see section 10.1), and emissions from hops transportation – despite the fact they are transported from other continents – are still negligible (less than 1% of the total footprint of the beer).

It is interesting to note that the transportation of the hops from across the world is responsible for a similar amount of emissions as the transportation of the barley a short distance in the UK. This is due to the larger weight of barley transported, compared to the hops. The weight being transported clearly has a larger impact here than the distance transported. In section 10.3.1, a sensitivity analysis is undertaken which illustrates the impact that importing all the hops from different countries can have on the overall footprint of the beer.

As shown in figure 8 below, of the hops cultivation emissions, nitrogen fertiliser (fertiliser production and N2O emissions from soils) is responsible for the majority of the emissions (nearly one third), as with the cultivation of the barley.

Figure 8: Breakdown of hops cultivation emissions

**3.5 END NOTES**

**3.5.1 Data sources**

*Hops from USA*

Approximately three quarters of the hops used in the Pale Ale are from the USA, and are supplied by two companies.

In a personal communication, one of the suppliers - Simply Hops - supplied estimates of inputs and outputs for the cultivation of the USA hops taken from data from farm records (Dean Monshing, January 2014). The supplier was not able to confirm the percentage of their farms that provided the data, so it cannot be confirmed whether this is a representative sample. The estimates are therefore cross-checked with other secondary data sources where possible.

The other supplier provided the results of an environmental impact study. However, when contacted, the author of the report could not provide details of the key assumptions, or a breakdown of emissions, so the results are not used here. The other supplier did however provide details of the journey that the hops take when imported to the UK, which are used in the transportation calculations in appendix B.

*Hops from Germany, Australia and New Zealand*

None of the suppliers of hops from Australia, New Zealand or Germany were able to provide data, and no life cycle data or carbon footprint studies of hops cultivated in these countries are publicly available. The emissions from cultivating the hops from these countries are therefore estimated using the USA hops emissions per hectare. However transport emissions specific to Germany, Australia and New Zealand are calculated (see appendix B).

**3.5.2 Fertiliser**

Estimates supplied by Simply Hops are in line with findings of research on fertiliser requirements for hops (Gingrich et al. 2000).

*Fertiliser Production emissions*

Estimates for fertiliser production emissions from cradle to gate (raw material extraction to factory gate) in North America are taken from Kool et al. (2012). They are estimated as follows:

|  |  |
| --- | --- |
| **Fertiliser** | **Emission factor** |
| Ammonium Nitrate | 2.8118kgCO2e/kg fertiliser (34%N) |
| Phosphorous | 0.36kg CO2e/kg P2O5 fertiliser |
| Potassium sulphate | 0.19kg CO2e/kg K20 fertiliser |

Table 24: Fertiliser production emission factors in the USA

*Nitrous Oxide emissions from soils*

According to Simply Hops, only one nitrogen fertiliser was used for the cultivation of the hops. The calculation of the amount of nitrogen applied is shown in table 25. The calculations for the direct and indirect nitrous oxide soil emissions as a result of fertiliser applications to hops are shown in table 26 below. See appendix C for an explanation of emission factors.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **CALCULATION NITROGEN (N) APPLIED** | | |
| **% N** | **Quantity fertiliser applied (kg/ha)** | **Quantity N applied (kgN/ha)** |
| Ammonium nitrate | 35% | 100 | 35 |

Table 25: Calculation of quantity of N applied (% N from Wood and Cowie 2004)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Quantity N applied (kgN/ha)** | **CALCUATION N2O EMISSIONS** | | | | **GWP of N** | **EMISSIONS (kgCO2e)** |
| **Emission Factor (EF) - Direct N2O emissions** | **EF – leaching** | **EF - volatisation** | **Total N2O emissions** |
| Ammonium nitrate | 35 | 0.01 | 0.01 | 0.0075 | 0.9625 | 298 | **286.825** |

Table 26: CO2e emissions calculations for N2O soil emissions from fertiliser application to hops (emission factors (EF) from IPCC 2006)

**3.5.3 Pesticides**

Pesticide use data was supplied by Simply Hops and was used in the calculations. Estimates supplied by Simply Hops were similar to data in the Defra pesticide survey (Defra 2013b), but there was a higher use of insecticides.

As with barley (see section 2.4.4), an average of the emission factors from Lal (2004) and West and Marland (2001) was used.

**3.5.4 Water**

Drip irrigation is used by all the Simply Hops farms. Drip irrigation is an efficient watering system, because it provides a direct source of water and fertiliser to the plant’s root system. It also minimises run off, erosion and evaporation than other types of irrigation (Yakima Chief 2013).

A report by West and Marland (2004) estimated emissions for irrigation by farm pump in the USA to be 239kgCO2e/ha/year.

**3.5.5 Energy**

Simply Hops provided an estimate of 64.2kg diesel per hectare for hop cultivation, which is similar to the industry guidance estimate (BIER 2014).

**3.5.6 Waste**

Simply Hops reported that all green waste (hop vegetative material) is returned to the field as soil amendment.

Simply Hops provided estimates of landfill waste. These emissions from landfill waste are shown to be negligible for hops cultivation and are therefore excluded (see appendix A).

**3.5.7 Detailed emissions calculation**

Detailed calculations of emissions per hectare for hops cultivation are shown in table 27 below.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **ESTIMATE** | | **EMISSION FACTOR** | | | **EMISSIONS (kgCO2e/ha)** |
|  | **Quantity** | **Per** | **Emission factor** | **Source** | **GWP** |
| **FERTILISER PRODUCTION** | | | | | | |
| Nitrogen fertiliser | 100 | kg/ha | 2.1881 | Kool et al. 2013 |  | 218.81 |
| Phosphorous fertiliser | 50 | kg/ha | 0.36 | Kool et al. 2013 |  | 18 |
| Potassium Fertiliser | 100 | kg/ha | 0.19 | Kool et al. 2013 |  | 19 |
| **N2O EMISSIONS FROM SOILS** | | | | | | |
| N2O direct emissions | 35 | kgN/ha | 0.01 | IPCC 2007 | 298 | 104.3 |
| N2O emissions from soils - volatisation | 35 | kgN/ha | 0.01 | IPCC 2007 | 298 | 104.3 |
| N2O emissions from soils - leaching | 35 | kgN/ha | 0.0075 | IPCC 2007 | 298 | 78.23 |
| **PESTICIDES** | | | | | | |
| Herbicide | 1.5 | kg/ha | 5.50119 | Lal 2004 |  | 8.25 |
| Insecticide | 1 | kg/ha | 5.1 | lal 2004 |  | 5.1 |
| Fungicide | 1 | kg/ha | 4.53867 | Lal 2004 |  | 4.54 |
| **ENERGY** | | | | | | |
| Water irrigation |  |  |  | Lal 2004 |  | 239 |
| Diesel | 64.2 | kg/ha | 3.0705 | DECC/Defra 2012 |  | 197.13 |
| **EMISSIONS PER HECTARE FOR HOPS CULTIVATION** | | | | | | **996.65** |

Table 27: Hops emission calculation

**3.5.8 Hops transportation**

Yakima Chief – one of the hops suppliers – provided details of the journey from the hop farms in the USA to the brewery in Bermondsey, which involves the use of trucks, train and ship (see appendix B). Details were not provided for journeys from the other countries, so the following assumptions were made:

* The Australian hops are taken from Bushy Park in Tasmania to the port of Hobart by HGV where they travel by ship to Southampton in the UK;
* The New Zealand hops are shipped from the Port of Nelson (they are grown in Nelson) to Southampton in the UK;
* Since it is not known whether the containers are refrigerated or not, the higher emission factor for refrigerated container shipping is used as a conservative estimate;
* The Australian and New Zealand hops are then transported by HGV from Southampton to Bermondsey; and
* The German hops travel from Nuremberg (the company’s headquarters) to the UK by HGV, crossing the channel by roll-on roll-off ferry.

Emission factors used for hops transportation are explained below.

*Truck emission factor*

See appendix C – emission factors.

*Rail emission factor*

The DECC/Defra (2012) emission factor for diesel/electric freight rail is used for transporting the hops from Seattle to Montreal in appendix B.

*Shipping emission factors*

A refrigerated container is used to ship the hops cultivated in the USA from Montreal to the UK. An emission factor for refrigerated cargo is therefore used here. As a point of note, the emission factor per tonne.km for refrigerated cargo is 0.0031kgCO2e, compared to a tonne.km for general cargo of only 0.0026kgCO2e (16% lower than refrigerated cargo) for the same size vessel (DECC/Defra 2012). However given the low weight of hops transported for each hectolitre of beer, the difference is likely to be negligible.

**4. MALTING (6.97kgCO2e)**

All the malt used by the brewery is from Simpson Malt – a maltster in Suffolk. Malting the barley is an energy-intensive process (MAGB 2011)[[7]](#footnote-7). Emissions are produced from:

* The energy used in the malting process (section 4.1); and
* The transportation of the malt to the brewery (section 4.2).

Figure 9 illustrates the process flow for the malting stage, from receipt of the barley up until the delivery of the malt to the brewery.

BARLEY

**MALTING – DRYING, STEEPING, DECULMING, MILLING GRIST**

**MALT**

BY-PRODUCTS

WASTE

BREWERY

**MALT TRANSPORT**



WASTE WATER

Figure 9: Process flow for malting stage

* **Light green = previous stage, Barley production**
* **Dark green = included processes**
* **Grey = excluded processes**
* **Blue = next stage, brewery stage**

Excluded from this stage are:

* By-products; and
* Waste (see section 4.4.2).

**4.1 MALTING PROCESS (6.21kgCO2e)**

Estimates of inputs and outputs were supplied per tonne of barley (not malt) by Simpsons Malt[[8]](#footnote-8) and are summarised in table 28 below. Some of the inputs and outputs are discussed in more detail in the chapter end notes (section 4.4).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **INPUT** | **Quantity** |  | **OUTPUT** | **Quantity** |
| Barley | 1 tonne |  | Malt | 830kg |
| Gas | 880kWh |  | Culm (by-product) | 20kg |
| Electricity | 165kWh |  | Grain screenings (by-product) | 10kg |
| Water | 2.5m3 |  | Culm/grain dust (by-product) | 5kg |
|  |  |  | Waste water | 2.5m3 |
|  |  |  | Recycled waste | 50kg |
|  |  |  | Landfill waste | 0kg |

Table 28: Inputs and outputs per tonne of barley (data supplied by Simpsons Malt)

* Black text highlights included elements
* Grey text highlights excluded elements
* Green text highlights elements that are calculated in other sections

The reason 830kg malt is produced from one tonne of barley is that, during the malting process, water is lost from the barley through moisture loss and conversion of starch to simpler sugars during germination which creates by-products (the rootlets) which are then removed.

**4.1.1 Allocation of malting emissions per functional unit**

According to the brewery, approximately 21.14kg of malt is used per hectolitre (functional unit) of Pale Ale.

**4.1.2 Emissions calculation for malting**

By applying UK Government emission factors (DECC/Defra 2013) to the estimated quantities of gas and electricity used (supplied by Simpsons Malt), the emissions for the malting stage per functional unit were calculated in table 29 below. Emissions from the energy used to pump the water are accounted for in the energy use emissions estimate.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **INPUT** | **ESTIMATE / TONNE BARLEY** | | **ESTIMATE / TONNE MALT** | | **EMISSION FACTOR** | | **TOTAL EMSSIONS (kgCO2e)** | |
| **Quantity** | **Unit** | **Quantity** | **Unit** | **Quantity** | **Source** | **Per tonne malt** | **Per FU** |
| Gas | 880 | kWh | 1056 | kWh | 0.1852 | DECC/Defra 2013 | 195.58 | 4.13 |
| Electricity | 165 | kWh | 198 | kWh | 0.4964 | DECC/Defra 2013 | 98.28 | 2.08 |
|  |  |  |  |  |  |  | **TOTAL** | **6.21** |

Table 29: Calculation of emissions from malting per functional unit (FU)

**4.2 MALT TRANSPORT (0.76kgCO2e)**

The emissions from transporting the malt by truck a distance 172km to the brewery are 0.76kgCO2e per functional unit. Details are shown in appendix B.

**4.3 DISCUSSION**

Emissions from the malting stage are summarised in table 30 below.

|  |  |
| --- | --- |
|  | **Emissions (kgCO2e/FU)** |
| Malt production | 6.21 |
| Malt transport | 0.76 |
| **Total malt emissions** | **6.97** |

Table 30: Total emissions from malting stage per functional unit (FU)

Figure 10: Breakdown of emissions from malting stage

As shown in figure 10, the majority of the emissions from the malting stage are from the malting process itself.

A comparison with a Carbon Trust report (2011) was made to check whether the data supplied by Simpsons Malt is similar to industry averages[[9]](#footnote-9). The energy use per tonne of malt at Simpsons Malt is 1,254kWh, which is higher than the Carbon Trust report figure of 1,181kWh. Based on the data supplied, energy used by Simpsons Malt can therefore be assumed to be approximately 5% above the industry average. This could indicate that there are perhaps efficiencies that could be made at Simpsons Malt, or that there are other more energy efficient malt suppliers in the UK.

After reviewing the findings of this assessment, Simpsons Malting responded to say that the Tivetshall site (which malts the barley that is used by the Kernel) has small batch sizes (120 tons per batch) which make it less efficient. Their second site is more efficient where the batch sizes are bigger (440 tons per batch), because it takes less gas to dry the malt of a big batch per ton compared to a small batch. Simpsons Malt also stated that it intends to switch from kerosene as its main supply to gas next year, which should give better yield and efficiency (Pierre –Antoine Kantor, personal communication, August 2014).

**4.4 END NOTES**

**4.4.1 Energy use**

Estimates of energy use include:

* Energy used by the kiln;
* Energy to pump the water from a borehole on site; and
* Hotel load energy use from the whole malting site e.g. lighting and climate control.

**4.4.2 Waste**

An estimated 35kg of each tonne of barley ends up as by-products – malt culms, screenings and dust – of the malting process.

Composted and landfill waste were shown to be negligible (see appendix A).

**4.4.3 Waste water**

Waste water is sent through reed beds and then treated anaerobically by sludge, which has to be pumped out approximately once a week. The treated water is then pumped into the local river. All energy used for pumping is accounted for in the energy emissions in section 4.4.1, so an emission estimate is not given specifically for waste water.

**5. PACKAGING (44.38kgCO2e)**

Emissions are caused by the production of the packaging and the inbound transportation of the packaging to the brewery. Table 31 below summarises the different types of packaging involved in the life cycle of the beer.

|  |  |  |  |
| --- | --- | --- | --- |
| **Section of this report** | **Type of packaging** | **Description** | **Packaging included in this study** |
| 5.1 | Primary packaging | Container | Glass bottle |
| 5.2 | Secondary packaging | Materials that are part of the functional unit as sold | Crown caps  Paper labels |
| 5.3 | Transit packaging | Materials used to wrap, pack and transport the empty bottles to the brewery, and the full beer bottles for distribution | Wood pallet  Cardboard boxes  Plastic pallet wrap |

Table 31: Different types of packaging in the life cycle of the beer

Figure 11 below illustrates the process flow for each packaging type in this stage, up until the delivery of the packaging to the brewery.

**RAW MATERIAL EXTRACTION AND PROCESSING**

**RECYCLED CONTENT PROCESSING**

**PRODUCTION PROCESS**

**DISPOSAL OF CAPS AND PALLET**

BREWERY

**PACKAGING TRANSPORT**



Figure 11: Process flow for packaging stage

* **Orange text = included processes in this stage**
* **Blue text = next stage, brewery**

**5.1 PRIMARY PACKAGING (GLASS BOTTLES) (39.83kgCO2e)**

The calculation of the emissions from the primary packaging – the glass bottles – includes emissions from:

* Glass bottle production (section 5.1.1);
* Transit packaging (for the glass bottles) production (section 5.1.2); and
* Transporting the bottles in the transit packaging to the brewery (section 5.1.3).

**5.1.1 Glass bottle production (38.71kgCO2e)**

Although not publicly available, when contacted Owens Illinois (O-I) – the manufacturer of the bottle used by the brewery – supplied emissions data from a study that it had carried out of a generic glass bottle produced in Europe by O-I (Tim Neal, O-I, personal communication, 2014) (see section 5.5.1 in the chapter end notes for data supplied). However, no data was available from the manufacturer for the *exact* bottle used by the brewery.

There are some important differences between the exact bottle used by the brewery and the assumptions used in the O-I study (see table 32 below).

|  |  |
| --- | --- |
| **O-I study** | **Kernel bottle** |
| For an average glass bottle (O-I produces green, clear and amber bottles) | An amber glass bottle |
| Recycled content rate of 47% | Recycled content not given by manufacturer, but assumed to be around 20% for amber glass (British Glass 2014) |
| Electrical grid in Puglia, Italy assumed | Produced in UK, so UK electrical grid used |

Table 32: Differences between the bottle used by Kernel and bottle in O-I study

Due to the lack of details regarding the O-I study (i.e. method and assumptions used), and the many uncertainties regarding the relevance of the O-I data to the exact bottle used by the Kernel, where relevant, the O-I data was adjusted or replaced (using data from other sources) to suit the specifics of the bottle used by the brewery. This is shown in table 33 below.

|  |  |  |
| --- | --- | --- |
| **LIFE CYCLE STAGE** | **SOURCE OF EMISSIONS DATA** | |
| **Source** | **Why source chosen** |
| Raw Material Extraction | O-I | Only study with estimation for this stage |
| Raw Material Processing | O-I | Most relevant |
| Raw Material Transport | O-I And Enviros (2003) | Average of O-I and Enviros (2003) |
| Production Process | O-I | Based on data from manufacturing company |
| CO2e Reduction from Recycling | Adjusted O-I for 20% recycled content rate | Based on data from manufacturing company |

Table 33: Sources of data selected for use in this study

Further details regarding the data sources for the glass bottles and the impact from each life cycle process are given in the chapter’s end notes in section 5.5, as shown in table 34 below.

|  |  |
| --- | --- |
| 5.5.1 | **Data sources**   * OI * Enviros (2003) * Envirowise (2008) |
| 5.5.2 | **Processes**   * Raw material extraction * Raw material processing * Raw material transport * Production process * Recycled content |

Table 34: Chapter end note sections

*5.1.1.2 Allocation of emissions per functional unit*

Calculations for the amount of glass required for one functional unit are shown in table 35 below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **QUANTITY / HECTOLITRE** | | | **WEIGHT** | |
|  | **Amount** | **Waste (at brewery)** | **Quantity incl. Waste** | **Unit weight (kg)** | **kg / FU** |
| **Glass bottles** | 200 | 0.5% | 201 | 0.3 | 60.3 |

Table 35: Calculation of the amount of glass required for one functional unit (FU)

*5.1.1.3 Emissions calculation for glass bottles*

Table 36 below summarises the emissions estimates used and total glass bottle emissions.

|  |  |  |
| --- | --- | --- |
|  | **AMBER GLASS EMISSIONS (20% RECYCLED CONTENT)** | |
| **kgCO2e/kg glass** | **kgCO2e/FU (60.3kg glass)** |
| Raw Material Extraction | 0.04 | 2.41 |
| Raw Material Processing | 0.18 | 10.85 |
| Raw Material Transport | 0.01 | 0.78 |
| Production Process | 0.45 | 27.14 |
| CO2e Reduction from Recycling | -0.06 | -3.59 |
| **TOTAL** | **0.62** | **37.59** |

Table 36: Emissions estimates for glass bottle production per functional unit (FU). For sources of emissions estimates, see section 5.5.1

*5.1.1.4 Discussion*

Table 37 below compares:

* Emissions estimates from different sources using the same recycled content rates (e.g. 20% recycled rate for both estimate 2 from O-I and estimate 4 from Enviros (2003)); and
* Emissions estimates from the same source but using different recycled rates (e.g. O-I estimate 1 for 47% compared to estimate 2 from O-I for 20%).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **ESITMATE 1** | **ESTIMATE 2** | **ESTIMATE 3** | **ESTIMATE 4** |
| **Data source** | **O-I LCA (kgCO2e/kg glass)** | **O-I LCA (kgCO2e/kg glass)** | **Enviros (kgCO2e/kg glass)** | **Enviros (kgCO2e/kg glass)** |
| **Recycled content** | 47% | 20% | 47% | 20% |
| **PROCESS** | | | | |
| Raw Material Extraction | 0.04 | 0.04 | 0.05 | 0.05 |
| Raw Material Processing | 0.18 | 0.18 |
| Raw Material Transport | 0.02 | 0.02 | 0.01 | 0.01 |
| Production Process | 0.45 | 0.45 | 0.78 | 0.78 |
| CO2e Reduction from Recycling | -0.14 | -0.06 | -0.15 | -0.06 |
| **Total carbon footprint** | **0.55** | **0.63** | **0.69** | **0.78** |

Table 37: Comparison of emissions (kgCO2e/kg glass) estimates from different reports

In both the O-I and Enviros studies, when the recycled content rate is reduced from 47% to 20%, the emission per kilo of glass increase by approximately 12%.

From the table above, total emissions from production of the O-I bottle (estimate 2) are lower than the UK industry estimate (estimate 4) for the same recycled content rate (20%) in the Enviros report (2003). The O-I estimate for ‘production process’ – which is made using data from 2011 – is lower than the Enviros estimate which is based on data from 2003. Furnaces are now available that are more energy efficient (Carbon Trust 2012). One reason for the difference could therefore be that the furnaces used to produce the O-I bottles in 2011 are more energy efficient than the average furnace used in the UK in 2003. It could also be that O-I is a more energy efficient manufacturer than the UK average, but this cannot be confirmed due to the lack of details regarding the study.

**5.1.2 Transit packaging (glass bottles to brewery) production (0.51kgCO2e)**

A substantial amount of transit packaging is used for transporting the bottles to the brewery. A decision was therefore made to include this packaging in this study.

Wooden pallets are used to transport the bottles from the manufacturer to the brewery. The brewery uses these same pallets for the distribution of the full beer bottles (see section 5.3). The pallets are then recovered by a pallet recovery company and returned to the bottle manufacturer.

Cardboard layers are used to separate the empty bottles as they are loaded onto the pallet, and heavy duty plastic wrap is used to wrap the pallet.

*5.1.2.1 Allocation for 1 functional unit*

Quantities of materials used per pallet were supplied by the bottle manufacturer. One pallet holds 1,400 bottles. 201 bottles are manufactured per functional unit (including 1 bottle wasted). One functional unit therefore requires 14% of a pallet.

|  |  |
| --- | --- |
| Number bottles contained on one pallet | 1,400 |
| Number bottles in one functional unit | 201 |
| % pallet required for one functional unit | 14% |

Table 38: Calculation of percentage of a pallet required per functional unit

Quantities of packaging used per pallet are therefore multiplied by 0.14 to give the quantity per functional unit, shown in table 39 below.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Quantity/pallet** | **% pallet / FU** | **Kg / FU** |
| Wood pallets | 1 | 14% | 0.14 |
| Plastic pallet wrap (kg) | 1.39 | 14% | 0.19 |
| Cardboard layers (kg) | 0.6 | 14% | 0.08 |

Table 39: Calculation of qualities per functional unit (FU)

Each pallet is used approximately 75 times over its lifetime (Chicago Manufacturing Centre 2014). When this is taken into consideration, each journey to transport a functional unit of empty bottles could therefore be said to be responsible for 0.19% of the emissions of the whole life of the pallet.

|  |  |
| --- | --- |
|  |  |
| % pallet per FU | 14% |
| % pallet lifetime (75 journeys) for 1 journey | 1.33% |
| % lifetime of a pallet required by one journey for one FU | 0.19% |

Table 40: Allocation of transit packaging materials per functional unit (FU)

*5.1.2.2 Emissions calculation*

Emission factor data sources are analysed in section 5.5.3 in the chapter’s end notes. Table 41 below shows the calculations for the transit packaging emissions.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **QUANTITY** | **EMISSION FACTOR** | | | **TOTAL FOOTPRINT PER HL (kgCO2e)** |
|  |  | **Factor** | **per** | **Source** |
| Wood pallets (% pallet allocation) | 0.19% | 20.67 | pallet | Anil (2010) | 0.04 |
| Plastic pallet wrap (kg) | 0.19 | 2.13 | kg | Plastics Europe (2013) | 0.41 |
| Cardboard layers (kg) | 0.08 | 0.75 | kg | FEFCO and CEPI (2013) | 0.06 |
| **TOTAL** | **0.51** | | | | |

Table 41: Transit packaging emissions calculations per functional unit (FU) for transporting the empty bottles

**5.1.3 Transporting the bottles to the brewery (0.61kgCO2e)**

The weight of the bottles and their associated transit packaging is calculated in table 42 below.

|  |  |
| --- | --- |
| **Packaging** | **Weight (kg)/FU** |
| Glass bottles | 60.3 |
| Pallet | 4.2 |
| Plastic wrap | 0.2 |
| Cardboard | 0.08 |
| **TOTAL** | **64.78** |

Table 42: Calculations for the freight weight of the bottles and transit packaging for one functional unit (FU)

As shown in appendix B, the emissions from transporting the bottles and their associated transit packaging a distance of 43km by HGV are 0.61kgCO2e per functional unit.

**5.2 SECONDARY PACKAGING (1.27kgCO2e)**

The calculation for the emissions from the secondary packaging includes the:

* Production of the packaging materials (section 5.2.1); and
* Transportation of the packaging to the brewery (section 5.2.2).

**5.2.1 Secondary packaging production (1.07kgCO2e)**

*5.2.1.1 Allocation for 1 functional unit*

Quantities of secondary packaging used per hectolitre were supplied by the brewery. The allocation of materials per functional unit is shown in table 43 below, including estimates provided by the brewery for wastage.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **QUANTITY / FU** | | | **WEIGHT (KG)** | |
|  | **Amount** | **Waste (at brewery)** | **Quantity incl. Waste** | **Unit weight** | **Per FU** |
| **Steel bottle crowns** | 200 | 1% | 202 | 0.002 | 0.42 |
| **Paper labels** | 200 | 2.5% | 205 | 0.0007 | 0.15 |

Table 43: Allocation of secondary packaging materials per functional unit

*5.2.1.2 Emissions calculation*

Emission factor data sources are analysed in the chapter’s end notes in section 5.5.4.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **QUANTITY / FU (KG)** | **EMISSION FACTOR (EF)** | **EF SOURCE** | **EMISSIONS PER FU (kgCO2e)** |
| **Steel bottle crowns** | 0.42 | 2.33 | APEAL (2014) | 0.99 |
| **Paper labels** | 0.15 | 0.556 | Norske Skorg (2012) | 0.08 |
| **Total** | **1.07** | | | |

Table 44: Emissions calculation for secondary packaging per functional unit (FU)

**5.2.2 Transport for secondary packaging (0.2kgCO2e)**

Emissions from the inbound transportation of the packaging materials are summarised in table 45 below (see appendix B for more details).

|  |  |  |
| --- | --- | --- |
|  | **Labels** | **Caps** |
| **Where they come from** | Girona, Spain | Kosice, Slovakia |
| **Emissions per functional unit** | 0.04kgCO2e | 0.16kgCO2e |
| **Total emissions per functional unit** | 0.2kgCO2e | |

Table 45: Emissions from secondary packaging transport to brewery

**5.3 DISTRIBUTION TRANSIT PACKAGING (3.28kgCO2e)**

Emissions from distribution transit packaging come from:

* The packaging production (section 5.3.1); and
* Transportation of the packaging to the brewery (section 5.3.2).

**5.3.1 Distribution transit packaging production (3.01kgCO2e)**

The types of transit packaging used for distribution are similar to section 5.1.2 above for the empty bottles. The main difference is that the bottles are put in 12-bottle cardboard boxes for distribution. Quantities of transit packaging were provided by the brewery per pallet and emission factors in appendix C were used.

*5.3.1.1 Allocation per functional unit*

Calculations for the allocation of packaging per functional unit are shown in table 46 below. Emissions from the pallet are accounted again in this section, because it counts as an additional journey.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **TRANSIT PACKAGING PER PALLET (FULL BEER BOTTLES)** | **QUANTITY** | | | |
| **Quantity/pallet** | **Kg each** | **% pallet / Hl** | **Kg per Hl** |
| Wood pallets | **1** | **30** | 14.00% | 4.2 |
| Plastic pallet wrap (kg) | **0.2** | **2.21** | 14.00% | 0.06 |
| Cardboard boxes (kg) | **117** | **0.233** | 14.00% | 3.81 |
| **TOTAL** |  |  |  | **8.08** |

Table 46: Calculations of quantities of transit packaging for distribution per functional unit (FU)

As calculated in section 5.1.2.2, the % of a pallet allocated to one single journey (of an estimated 75 journeys over its lifetime) is 0.19%.

*5.3.1.2 Emissions calculation*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **QUANTITY/FU** | **EMISSION FACTOR** | | | **EMISSIONS PER FU (kgCo2e)** |
| **Factor** | **Per** | **Source** |
| Wood pallet (% allocation of lifetime of pallet) | 0.19% | 20.67 | pallet | Anil (2010) | 0.04 |
| Plastic pallet wrap | 0.06 | 2.13 | kg | Plastics Europe (2013) | 0.13 |
| Cardboard boxes | 3.81 | 0.746 | kg | FEFCO and CEPI (2013) | 2.84 |
| **TOTAL** | **3.01** | | | | |

Table 47: Calculation of emissions from transit packaging for distribution per functional unit (FU)

**5.3.2 Transport of the transit packaging for distribution (0.27kgCO2e)**

Emissions from the inbound transportation of the transit packaging materials to the brewery are shown in table 48 below. For full details, see appendix B.

|  |  |  |
| --- | --- | --- |
|  | **Cardboard boxes** | **Shrink wrap** |
| **Where they come from** | Newmarket, UK | Istanbul, Turkey |
| **Emissions per FU** | 0.002kgCO2e | 0.27kgCO2e |
| **Total emissions per FU** | **0.27kgCO2e** | |

Table 48: Emissions from transportation of the transit packaging for distribution per functional unit (FU)

**5.4 DISCUSSION**

Packaging emissions by packaging type are summarised in table 49 and compared in figure 12 below.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Production (kgCO2e/FU)** | **Transport of materials to brewery (kgCO2e/FU)** | **Total (kgCO2e/ FU)** |
| **PRIMARY PACKAGING** | | | |
| Bottle | 38.71 | 0.61 | **39.83** |
| **Bottle transit packaging** |  |
| Pallet | 0.04 |
| Plastic wrap | 0.41 |
| Cardboard layers | 0.06 |
| **SECONDARY PACKAGING** | | | |
| Paper labels | 0.08 | 0.04 | **0.12** |
| Steel bottle crowns | 0.99 | 0.16 | **1.15** |
| **DISTRIBUTION TRANSIT PACKAGING** | | | |
| Pallet | 0.04 |  | **0.04** |
| Cardboard boxes | 2.84 | 0.002 | **2.84** |
| Plastic pallet wrap | 0.13 | 0.27 | **0.4** |
| **TOTAL** | **44.38** | | |

Table 49: Summary of packaging production and transport emissions per FU

Figure 12: Breakdown of emissions by packaging type (including their associated transport emissions to the brewery)

In this study, packaging is the most significant stage in terms of climate change impact of the life cycle of the beer. Of the packaging emissions, the glass bottle is responsible for the majority (90%) of the packaging emissions. However, as explained above, there is uncertainty with this figure, due to the unknown recycled content of the bottle, and the uncertainty regarding the relevance of the data to the exact bottle used by the Kernel.

**5.5 END NOTES**

**5.5.1 Glass bottle data sources**

Sources of data used in section 5.1.1 are analysed in table 50 below.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Source** | **Year** | **Recycled content rate** | **Region** | **Transparent?** | **Peer reviewed?** |
| **O-I** | Manufacturing company LCA | 2011 | 47% | Europe | No | No |
| **Enviros** | Industry report | 2003 | Unspecific | UK | Yes | No |
| **Envirowise** | Industry report | 2008 | Unspecific | UK | Yes | No |

Table 50: Data source analysis for glass bottle production

*O-I LCA*

Data supplied by O-I is shown in table 51 below.

|  |  |  |
| --- | --- | --- |
|  | | **O-I study (47% recycled content)** |
|  | | kgCO2e/kg glass |
| Raw Material Extraction | | 0.04 |
| Raw Material Processing | | 0.18 |
| Raw Material Transport | | 0.02 |
| Production Process | | 0.45 |
| Transport of Finished Goods | | 0.02 |
| CO2e Reduction from Recycling | | -0.14 |
| End-of-Life Management | | 0.01 |
| **Total emissions** |  | **0.58** |

Table 51: O-I LCA data for glass production in Europe (personal communication, January 2014, Tim Neal, O-I)

The data for the production process is based on averages of actual manufacturing data from O-I process plants across Europe (O-I 2010). The data for the other stages is from other secondary data sources (however O-I did not specify which).

*Enviros Consulting*

The Enviros Report for British Glass (2003) summarises the findings of a life cycle analysis (LCA) which investigated the impact of recycling on glass production emissions in the UK. The report uses a simplified LCA approach, whereby emissions savings from using recycled content are shown compared to the emissions from using 100% virgin materials.

*Envirowise report*

The main objective of the report (Envirowise 2008) was to consider the mass flow of glass through the UK economy, and it looks in detail at glass bottle recycling. Unlike the other sources of data, this report compares quantities of raw materials used to make different colour glass.

**5.5.2 Glass bottle production processes**

*Raw material extraction*

The estimate from the O-I study for raw material extraction was used in this study, because it is the only study that has an estimate specifically for raw material extraction.

*Raw material processing*

The types and amounts of raw materials used to make glass depend on the colour of the glass (Envirowise 2008), and each raw material has different extraction and processing emissions (IPCC 2006). Research was therefore undertaken to assess the raw material processing emissions of amber glass compared to green and clear, to understand whether the O-I data would be representative of the processing emissions from the raw materials used to make amber glass.

By applying IPCC (2006) and UK Government emission factors (DECC/Defra 2013) to the quantities of material inputs for each type of glass (according to Envirowise (2008)), the processing of raw materials per kilo of amber glass appears to create less emissions than clear glass but more than green glass (see table 52 below).

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Amber** | **Green** | **Clear** |
| Soda ash (kg/kg glass) | 0.18 | 0.16 | 0.47 |
| Emission factor (IPCC 2006) | 0.138 | 0.138 | 0.138 |
| **Soda ash emissions (kgC/kg glass)** | **0.03** | **0.02** | **0.06** |
|  |  |  |  |
| Limestone (calcite) (kg/kg glass) | 0.16 | 0.01 | 0.09 |
| Emission factor (Defra 2013) | 0.12 | 0.12 | 0.12 |
| **Total limestone emissions** | **0.02** | **0.00** | **0.01** |
|  |  |  |  |
| Dolomite (kg/kg glass) | 0 | 0.0455 | 0.04 |
| Emission factor (Defra 2013) | 0.13 | 0.13 | 0.13 |
| **Total Dolomite emissions** | **0** | **0.01** | **0.01** |
|  |  |  |  |
| **TOTAL EMISSIONS (kgC/kg glass)** | **0.05** | **0.03** | **0.08** |

Table 52: Carbon emissions from processing of soda ash, limestone and dolomite per kg glass for different colour glass (data from Envirowise 2008, table 10.a, p.41). (Only the emissions from raw materials that were judged to contribute over 1% of the total raw materials for amber glass (from Envirowise 2008, table 10a) were included in this analysis)

Amber glass emissions (0.05kgC/kg glass) are more or less the same as the average as the emissions of (0.053kgC/kg glass).The O-I estimate can therefore be assumed to be reasonable representative of amber glass raw material processing emissions.

*Raw material transport*

Two estimates were available for raw material transport. The Enviros (2003) estimate is based on glass production in the UK, whereas the O-I estimate is a European average. However the O-I estimate is from the actual manufacturer of the bottle and is more recent.

This part of the process is not a significant contributor to the total emissions from the glass bottle, so rather than conducting a sensitivity analysis, an average is taken of the two.

|  |  |  |
| --- | --- | --- |
| **Enviros** | **O-I** | **Average** |
| 0.006 kgCO2/kg glass | 0.02 kgCO2/kg glass | 0.013 kgCO2/kg glass |

Table 53: Average of two data sources for transport of raw materials

*Production process*

In terms of combustion emissions for the production of the glass, the emissions per kilo of amber glass are only around 1% above the average emissions for all types of glass (calculations made using data from Envirowise (2008) table 10a). This would make a difference of 0.005kgCO2e/kg glass. Since the difference is only very small, and the O-I data is only supplied with two decimal places, the average emissions for manufacturing in the O-I study are used for this study.

The estimate in the O-I study for production process assumes the Italian electricity grid is used. Emissions from electricity generation in Italy are lower (0.40kgCO2e/kWh) than in the UK (0.46kgCO2e/kWh) (DECC/Defra 2013) where the bottle used by the Kernel is produced. An adjustment to the data was therefore not made here to take into account the UK electricity grid, because the production process emissions are not broken down into different energy inputs (e.g. electricity and gas) in the O-I study. However, it is likely that the figure for the emissions for the production process is an underestimate for UK production using the UK grid.

*Recycled content*

There are many advantages to using recycled glass in the manufacturing of glass bottles. It avoids the emissions associated with raw material extraction and processing. Also, during the production process (which is responsible for a large percentage of the bottle production emissions (Enviros 2003)), the temperature required to melt the recycled glass is lower than for melting the raw materials (Envirowise 2008). Therefore the greater the recycled content, the lower the production emissions.

The recycled content rate for amber glass in the UK was approximately 20% in 2012 – far lower than the 80% recycled content rate for green glass (British Glass 2014) [[10]](#footnote-10) and the assumed 47% recycled content rate in the O-I study[[11]](#footnote-11). Since the manufacturer, O-I, was unable to confirm the recycled content of the amber glass bottle, the UK average of 20% recycled content for amber glass is assumed in this study. Adjustments were made to the O-I data to reflect the lower recycled content rate, using the calculation in table 54 below.

|  |  |
| --- | --- |
| Production emissions (kgCO2e/kg glass) | 0.45 |
| Emissions savings for 47% recycled content (kgCO2e/kg glass) (from O-I) | 0.14 |
| Emissions savings for 20% recycled content rate (kgCO2e/kg glass) | 0.06 |

Table 54: Calculation of emissions savings 20% recycled content, based on O-I data

As shown in table 55 below, per functional unit (60.3kg glass), a bottle with 20% recycled content has production emissions that are 4.82kgCO2e higher per functional unit compared to a bottle with 47% recycled content.

|  |  |  |
| --- | --- | --- |
|  | **kgCO2e/kg glass** | **kgCO2e/FU** |
| Production emissions 47% recycled content | 0.31 | 18.69 |
| Production emissions 20% recycled content | 0.45 | 23.52 |
| **Difference** | **0.14** | **4.82** |

Table 55: Calculation of difference in production emissions between 47% and 20% recycled content rates

**5.5.3 Transit packaging for glass bottles**

Sources of emission factors are listed in table 56 below.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Packaging type** | **Source** | **Source type** | **Transparent** | **Peer reviewed?** |
| Wood pallet | Anil (2010) | LCA - student thesis | Yes | No |
| Plastic wrap | Plastics Europe (2013) | LCA | Yes | Yes |
| Cardboard | FEFCO and CEPI (2013) | LCA | Yes | Yes |

Table 56: Sources of emission factors for transit packaging

**5.5.4 Secondary packaging emission factors**

Sources of emission factors are listed in the table 57 below.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Packaging type** | **Source** | **Source type** | **Transparent** | **Peer reviewed?** |
| Steel bottle crowns | APEAL (2014) | LCA | Yes | Yes |
| Paper labels | Norske Skorg (2012) | LCA | Yes | Yes |

Table 57: Emission factor sources for secondary packaging

**6. BREWERY AND WAREHOUSING (7.74kgCO2e)**

To make the Pale Ale, the malt is crushed in roller mills to produce ‘grist’ – a coarse flour which is then ‘mashed’ in a mash tun with hot water. The wort – a sweet brown liquid – is drawn off and then boiled with the hops in large vessels, before being cooled in a heat exchanger. Yeast is then added to the wort which reacts with the sugars to produce alcohol and carbon dioxide, and it is left to ferment for several days before being bottled using a bottling machine.

The Pale Ale is then bottle conditioned, meaning it undergoes a stage of secondary fermentation in the bottle. Described by the Campaign for Real Ale (CAMRA 2014) as ‘real ale’, bottle conditioned beer has a fresh and natural flavour. This beer is unpasteurised and not artificially carbonated. The beer is then stored in the brewery building, which also serves as a warehouse, until it is collected for distribution.

Emissions were considered from all activities that are undertaken at the brewery (brewing, bottling and warehousing). Figure 13 below illustrates the process flow for the brewery and warehousing stage, from the receipt of the ingredients and packaging up until the bottling and warehousing, where the beer is ready for the next stage – distribution.

MALT

HOPS

YEAST

SUGAR

**BREWING – Mashing and wort boiling, cooling, fermentation, refrigeration**

PACKAGING

**BOTTLING**

**BEER**

EFFLUENT

**WASTE WATER**

BY-PRODUCTS

**WAREHOUSING**

DISTRIBUTION

**WATER**

Figure 13: Process flow for brewery and warehousing stage

* **Blue = included processes**
* **Grey = excluded processes**
* **Dark green, green and orange = previous stages**
* **Purple = next stage, distribution**

The inputs and outputs per functional unit (hectolitre) supplied by the brewery are shown in table 58 below.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **INPUTS / HECTOLITRE** | **Quantity** |  | **OUTPUTS / HECTARE** | **Quantity** |
| Electricity | 14.08kWh |  | Beer | 1hl |
| Gas | 0.67m3 |  | Waste Water | 0.19m3 |
| Water | 0.38m3 |  | Effluent | 0.01m3 |
| Malt | 21.14 kg |  | Yeast and trub | 2.50kg |
| Hops | 0.83 kg |  | Spent hops | 2.50kg |
| Yeast | 0.05 kg |  | Spent malt | 42.29kg |
| Sugar (Priming) | 0.35kg |  |  |  |

Table 58: Inputs and outputs per hectolitre (supplied by the Kernel brewery)

* Black text highlights included elements
* Grey text highlights excluded elements
* Green text highlights elements whose emissions are calculated in other stages

Excluded elements of this stage are:

* Waste, yeast and effluent treatment (no emissions information available);
* Sugar (de minimus source – see appendix A); and
* By-products.

Waste (including by-products, reuse and landfill waste) is discussed in more detail in the chapter’s end notes in section 6.4.1.

**6.1 ALLOCATION PER FUNCTIONAL UNIT**

Data for this stage was supplied by the brewery in relation to the total brewing output. Total inputs and outputs for the year were divided by the number of hectolitres produced, to give the inputs and outputs per hectolitre.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **DATA SUPPLIED** | | | **TOTAL BREWING OUTPUT (HL)** | **QUANTITY FOR 1HL** | |
|  | **Quantity** | **Unit** | **For** | **Amount** | **Unit** |
| Electricity | 59893 | kWh | Total brewing output | 4255 | 14.08 | kWh |
| Gas | 2865 | m3 | Total brewing output | 4255 | 0.67 | m3 |
| Water | 1610 | m3 | Total brewing output | 4255 | 0.38 | m3 |
| Waste Water | 800 | m3 | Total brewing output | 4255 | 0.19 | m3 |

Table 59: Calculation for the allocation of included inputs and outputs for 1 functional unit (FU) (1hl) of beer (all data supplied by the Kernel brewery)

**6.2 EMISSIONS CALCULATION**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **AMOUNT PER FU** | | **EMISSION FACTOR (EF)** | | | **EMISSIONS PER FU (kgCo2e)** |
|  | **Amount** | **Unit** | **EF** | **Per** | **Source** |
| Electricity | 14.08 | kWh | 0.45 | kg COe/kwh | DECC/Defra 2013 | 6.27 |
| Gas | 0.67 | m3 | 2.02 | kgCO2e/m3 | DECC/Defra 2013 | 1.36 |
| Water | 0.38 | m3 | 0.293 | kg CO2e/M3 | Thames Water 2012/13 | 0.1113 |
| Waste Water disposal | 0.19 | m3 | 0.27 | kg CO2e/m3 | Thames Water 2012/13 | 0.0001 |
| **TOTAL** | **7.74** | | | | | |

Table 60: Emissions calculation for brewing and warehousing per functional unit (FU)

**6.3 DISCUSSION**

According to a Carbon Trust report (2011b)[[12]](#footnote-12)on energy efficiency in the brewing sector, average energy consumption of UK breweries (for gas and electricity) is 37.5 kWh/hl and emissions are 10.4kgCO2/hl (Carbon Trust 2011b). Figure 14 below shows a graph of the energy use from the sites in the report.

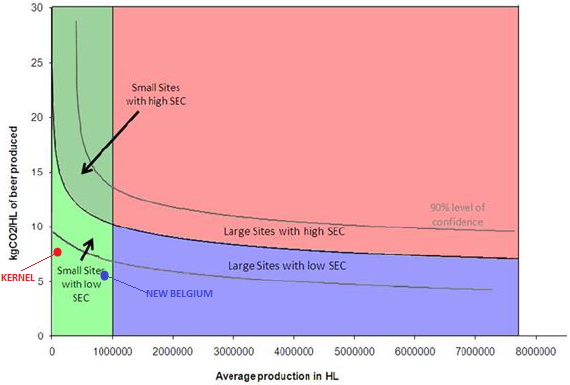


Figure 14: Total CO2 ratio vs total production from the Carbon Trust report (2011b), figure 9, page 15

* Red dot has been added to the graph to mark the ratio of CO2 from energy vs production of Kernel brewery
* Blue dot marks the ratio for New Belgium brewery
* ‘SEC’ is Specific Energy Consumption

For the Kernel brewery, the emissions from gas and electricity are 7.63kgCO2e/hl, which is approximately 26% lower than the UK industry average in 2009 of 10.4kgCO2e/hl (Carbon Trust 2011b). The Kernel has an output of just over 4,255hl. The ratio of production versus CO2 for the Kernel has been marked with a red dot on figure 14 above. According to the report (Carbon Trust 2011b), 90% of the breweries fall between the grey lines. It can therefore be assumed that the Kernel (which is below both lines) is in the top 10% of energy efficient breweries in the UK.

**6.3.1 Possible reasons why energy use is lower than average at the Kernel**

By analysing the breakdown of emissions from the Carbon Trust report (2011b) (see figure 15 below), differences between the Kernel brewery and the average UK brewery were identified and are discussed below.

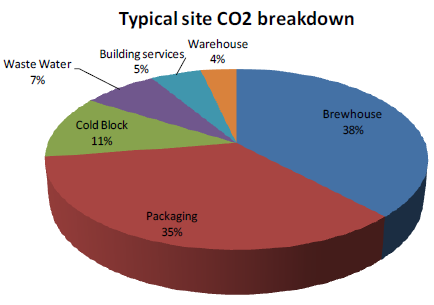
****

Figure 15: Brewery CO2 consumption breakdown for a typical 2Mhl brewery (Carbon Trust, 2011b, Figure 3, p. 11)

*Packaging*

Packaging is responsible for a significant amount of emissions – around 35% (Carbon Trust 2011b). Here packaging refers to pasteurisation and bottling. At the Kernel the beer is bottled but not pasteurised, so some of the potential ‘packaging’ emissions will be avoided.

*Refrigeration*

The Carbon Trust report (2011b) states that the refrigeration process (referred to as ‘cold block’ in figure 15 above) is responsible for 11% of emissions. According to the Kernel brewery, in order to ‘leave more things in’, the beer is cooled to about 7 degrees centigrade for a couple of days, whereas most breweries – especially those that produce lager (which is the majority of the beer produced in the UK (BBPA 2013) – cool the beer for longer and at lower temperatures (according to the Carbon Trust report (2011b)), which causes more emissions. By cooling the beer for a shorter amount of time, and at higher temperatures compared to average, emissions are likely to be lower than average for cooling for the Kernel brewery.

Most breweries will also keep the beer refrigerated after fermentation, but the Kernel brewery does not do this.

*Climate control*

The brewery is located in a converted railway arch, and it is quite well thermally insulated because of the thick ceiling supporting the railway above. The building stays very cool in summer and stays warmer in winter. The brewery is therefore likely to have lower climate control (or building services) emissions than the average brewery in a stand-alone building.

**6.3.2 Comparison of energy use between the Kernel brewery and New Belgium Brewery**

An interesting comparison can be made with the New Belgium Brewery in the USA (TCC 2008), where all electricity used is generated from renewable sources. A carbon footprint study of one their beers (TCC 2008) estimates brewery emissions from energy of 5.8 kgCO2e per hectolitre, which is lower than the energy emissions at the Kernel and is entirely down to the use of natural gas (processing, transmission, storage, distribution, combustion and allocation). This figure does not include any emissions from the manufacture of the renewable energy generation equipment, which the authors of the study believe to be negligible (TCC 2008).

It should be noted that New Belgium’s production (approximately 900,000HL) (New Belgium Brewery 2014) is approximately 200 times greater than the Kernel brewery. The ratio of energy use to output for New Belgium brewery has been marked on figure 14, and as with the Kernel brewery, the ratio is below the grey line.

*Water footprint comparison*

The Kernel brewery’s water input to beer output ratio of 3.8 to 1 for Pale Ale is lower than the UK brewing sector average of 4.2 to 1 (BBPA 2013b).

To put the use of water in the brewery stage into perspective with the overall water used throughout the life of the beer, the UK consultancy Water Strategies estimates 300 litres of water are used to make 1 litre of beer from cradle to grave (Kaye 2011). Over 98% of the water footprint (total water use) of a beer occurs before the raw materials arrive at the brewery, according to a report by WWF and SAB Miller (2013).

**6.4 END NOTES**

**6.4.1 Waste**

*6.4.1.1 By-products*

Spent malt is given to a farmer for free to feed horses. Spent hops and trub are picked up by a food waste recycling company for a fee paid by the Kernel.

*6.4.1.2 Reuse*

Bottle pallets are reused by the brewery for the distribution of the beer. Damaged pallets are sometimes reused in other ways – see figure 16 below.



Figure 16: Damaged pallets enjoy a new lease of life as a children’s sandpit at the brewery

6.4.1.3 Landfill and recycling waste

Brewery waste has been shown to be responsible for a negligible amount of emissions, in comparison to the overall footprint of a beer (TCC 2008). The New Belgium carbon footprint study (TCC 2008) estimated brewery waste was responsible for 0.0013% of the total footprint of the beer. However it should be noted that New Belgium brewery has a very successful waste management programme, and managed to divert 99% of its waste from landfill in 2013 (New Belgium 2014).

The Kernel brewery did not have a record of amounts of landfill waste by material type. Given the likely negligible contribution of the waste to the overall emissions, this was not taken any further.

**7. DISTRIBUTION TRANSPORT (3.02kgCO2e)**

Emissions are caused by the fuels that power the modes of transport used to distribute the beer. The 500ml bottles of Pale Ale are distributed in four different ways[[13]](#footnote-13):

* By light goods vehicle (LGV) for London deliveries (section 7.2);
* By heavy goods vehicle (HGV) (>17 tonnes) for distribution to the rest of the UK (section 7.3);
* Direct pick-up from the brewery by some wholesale customers; and
* Direct pick-up on open days (Saturdays) when customers can buy direct from the brewery.

Estimates of the percentage of beer that is sold through each distribution route were provided by the brewery and are shown in figure 17 below.

Figure 17: Breakdown of distribution by type

Figure 18 below illustrates the process flow of the distribution stage, from picking up the beer from the brewery warehouse, through to the delivery of the beer at the point of sale.

BREWERY AND WAREHOUSING

**LONDON**

**REST OF UK**

PICK-UP FROM BREWERY

RETAIL AND USE



Figure 18: Process flow for distribution stage

* **Blue** = the previous stage, brewery and warehousing
* **Purple** = included elements in distribution stage
* **Grey** = excluded elements
* **Pink** = next stage, retail and use

In accordance with industry guidance, where the customer picks up the beer from the brewery – for example on open Saturdays and with wholesale pickups – transportation emissions are not accounted for by the brewery, and are therefore excluded from this study (BIER 2014).

**7.1 DATA AND METHODOLOGY**

Primary data was supplied by the brewery for the two distribution routes that are included in this study.

There are two methods that are recommended for calculating emissions from transportation. The fuel-based methodology (multiplying fuel consumption by the emission factor for that fuel) is preferred over the distance-based methodology (calculated using distance based emission factors), because the data is generally more reliable (GHG Protocol 2005). Fuel data was available for the London distribution, so is used in that calculation (section 7.2). However fuel data was not available for the rest of the UK distribution, so the distance-based methodology was used instead (section 7.3).

The brewery does not own any vehicles, so all distribution is undertaken by third parties. In order not to double count emissions with the companies who own the transportation vehicles (should they decide to assess the carbon footprint of their operations), emissions from distribution transport are calculated using ‘scope 3’ emission factors (which are smaller than ‘scope 1’ emission factors from a company that owns its own transport) (DECC/Defra 2013).

|  |  |  |
| --- | --- | --- |
| **Distribution type** | **Primary data** | **Methodology** |
| London | Fuel consumption | Fuel-based methodology |
| Rest of UK | Average distance travelled per pallet | Distance-based methodology |

Table 61: Data and methodology for distribution transport

**7.1.1 General assumptions**

* According to the brewery, each full beer bottle and its associated secondary packaging weighs a total of 811.27g;
* The proportion of Pale Ale distributed by each distribution type is assumed to be the same as the proportion of the total output that is Pale Ale in 500ml bottles (i.e. of the beer distributed to London, 15% will be Pale Ale in 500ml bottles); and
* Transport is not refrigerated.

**7.2 LONDON DISTRIBUTION EMISSIONS (0.47kgCO2e)**

Table 62 summarises the assumptions and allocation calculation used for the London deliveries.

|  |  |
| --- | --- |
| **ASSSUMPTIONS** | |
| Kernel output 2013 | 4,255hl |
| % Kernel output delivered to London in 2013 | 54% |
| Amount delivered to London in 2013 | 2,297hl |
|  | |
| Fuel used for London deliveries 2013 | 3,428litres |
| Fuel used per hectolitre of beer | 1.5 litres |
|  | |
| **ALLOCATION** | |
| Amount delivered to London/FU | 0.54hl |
| Fuel used for 0.54hl of beer | 0.81 litres |

Table 62: Assumptions and allocation calculation for London deliveries

The calculation of emissions for London distribution is shown in table 63 below.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Vehicle type** | **Fuel (litres) /FU** | **Emission factor - indirect (diesel)** | **EF source** | **Emissions/share of FU (kgCO2e)** |
| Diesel van (class III) | 0.81 | 0.58 | DECC/Defra 2013 | 0.47 |

Table 63: Calculation of emissions from distributing 54% of the FU to London

It should be noted that it is assumed that the emissions are the same for each hectolitre of beer distributed to London. However, in fact, the freight weight per functional unit of bottled beer will be heavier than the freight weight of the beer distributed in disposable plastic kegs. This estimate should therefore be considered an underestimate.

**7.3 REST OF UK DISTRIBUTION (2.55kgCO2e)**

Emissions are calculated using a tonne.km emission factor, which is the amount of emissions from transporting one tonne one kilometre by a certain mode of transport (DECC/Defra 2013). The weight of the freight is multiplied by the distance transported, to give the tonne.km. Table 64 below shows the calculations for the freight weight for 200 bottles.

|  |  |
| --- | --- |
| **FREIGHT WEIGHT CALCULATIONS** | |
| Single full beer bottle weight (kg) | 0.81 |
| 200 full beer bottle weight (kg) | 162.20 |
| Transit packaging weight for 200 bottles (kg) | 8.08 |
| **Bottle and transit packaging weight for 200 bottles (kg)** | **170.28** |

Table 64: Freight weight calculations per functional unit

**7.3.1 Allocation per functional unit**

The calculation of the allocation of the freight weight distributed to the rest of the UK distribution is shown in table 65 below.

|  |  |
| --- | --- |
| **ASSSUMPTIONS** | |
| % FU delivered to rest of UK | 20% |
| Freight weight per FU (tonnes) | 0.17 |
| Freight weight per 20% FU (tonnes) | 0.03 |

Table 65: Allocation of freight weight per functional unit (FU)

**7.3.2 Emissions calculation for rest of UK distribution**

Calculations using the distance-based methodology are shown in table 66 below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Distance (km)** | **Vehicle type** | **Weight (tonne) (20% of FU)** | **tonne.km** | **Emission factor (tonne.km) (DECC/Defra 2013)** | **Emissions/share of FU (kgCO2e)** |
| 359.93 | HGV (class III) | 0.03 | 12.27 | 0.21 | 2.55 |

Table 66: Calculation of UK distribution emissions per functional unit (FU)

**7.4 DISCUSSION**

Total emissions for distribution are shown in table 67 below, and emissions are compared by distribution type in figure 19 below.

|  |  |
| --- | --- |
|  | **Emissions (kgCO2e/FU)** |
| London | 0.47 |
| Rest of UK | 2.55 |
| **TOTAL** | **3.02** |

Table 67: Total distribution transport emissions per functional unit (FU)

Figure 19: Breakdown of emissions from distribution

Although the amount of beer distributed to the rest of the UK is only 20% of the functional unit, it is responsible for 85% of total distribution emissions. London distribution, which involves shorter distances and a lightweight vehicle, is responsible for only 15% of emissions, despite distributing 54% of the beer. This shows that local distribution by LGV results in fewer emissions per hectolitre than distributing further afield by HGV.

Nearly one quarter of sales have zero emissions (for the brewery) because they involve customers picking up the beer direct from the brewery. However, where vehicles are used to transport the beer to the home or to the point of sale, there will be emissions but they are not accounted for in this study.

*Sensitivity analysis*

In order to evaluate the percentage sensitivity of the results to distribution route, an analysis was undertaken firstly assuming that all 200 bottles are distributed to London (table 68 below), and then assuming all bottles are distributed to the rest of the UK.

*London distribution*

|  |  |  |  |
| --- | --- | --- | --- |
| **Vehicle type** | **Fuel (litres) /HL** | **Emission factor - indirect (diesel)** | **Emissions/hl (kgCo2e)** |
| Diesel van (class III) | 1.5 | 0.5775 | 0.87 |

Table 68: Calculation of emissions for delivering 200 bottles to London

*UK Distribution*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Distance (km)** | **Vehicle type** | **Weight (tonne)** | **tonne.km** | **Emission factor (tonne.km)** | **Emissions/hl (kgCo2e)** |
| 359.93 | HGV (class III) | 0.17 | 61.19 | 0.21 | 12.69 |

Table 69: Calculation of emissions for delivering 200 bottles to rest of UK

As shown in this analysis, if all bottles per functional unit were delivered to the rest of the UK, the emissions would be 12.69kgCO2e. However if they were all delivered to London, emissions would only be 0.87kgCO2e – a difference of 11.82kgCO2e. Local distribution is shown here to result in big reduction in emissions compared to UK distribution.

*Comparison with other studies*

An interesting comparison can be made with distribution emissions for Fat Tire beer produced by the New Belgium Brewery, which is distributed nationally (across the USA) and internationally with associated emissions of 13.81kgCO2e/hl (TCC 2008), compared to the Kernel’s 3.02kgCO2e/hl. Possible reasons why the distribution emissions are considerably higher could be that Fat Tire beer travels an average of 793 miles by truck (exported beer does not seem to be included in this study) – over twice the distance of the average pallet for the ‘rest of UK’ Kernel distribution (TCC 2008). There are also no direct pick-up sales in the Fat Tire study.

Research by the Beverage Industry Environmental Roundtable (BIER 2011) found distribution transport of beer in Europe to be responsible for approximately 5.5kgCO2e/hl. The BIER research included several multi-national companies which are likely to distribute further than the Kernel. A comparison of the emissions from the Kernel distribution with the average Europe (BIER 2011) and Fat Tire (TCC 2008) distribution are shown in figure 20 below.

Figure 20: Comparison of emissions from distribution transport (kgCO2e/hl)

The conclusion of this comparison is that concentrating on local distribution for beer can have a big impact on the overall emissions of the beer – emissions savings of between 2-10kgCO2e per functional unit (compared to BIER 2011 and TCC 2008). In the case of the Kernel, it is shown to be just over half the European average distribution emissions.

**8. RETAIL AND USE (4.55kgCO2e)**

All sales are through small shops, pubs and restaurants – the brewery does not sell to supermarkets. Emissions are caused by the energy used (electricity and gas) at the point of sale, and to power the domestic refrigerator if the beer is cooled at home.

Figure 21 shows the process flow for this stage. Included in this stage of this study are the:

* Proportionate share of emissions from gas and electricity use at the point of sale, based on the % of sales at the point of sale that are Kernel 500ml Pale Ale; and
* Emissions from electricity used for domestic refrigeration of all beer sold at ambient temperature from the shop shelf (and therefore assumed to require home refrigeration).

DISTRIBUTION

WASTE DISPOSAL

**PUB/**

**RESTAURANT**

**SHOP**

**HOME FRIDGE**

Fugitive refrigerants and leaks

Fugitive refrigerants and leaks

Figure 21: Process flow for retail and use stage

* **Purple = previous stage, distribution**
* **Pink = included elements in this stage**
* **Grey = excluded elements from this stage**
* **Yellow = next stage, waste disposal**

Fugitive refrigerants and leaks are low for domestic and stand-alone glass-fronted beer coolers (IPCC 2006) and a study showed that they are negligible in comparison to the overall footprint of a beer (TCC 2008), so are excluded from this study.

In line with carbon footprint guidance (BSI 2011), also excluded are:

* Consumer travel to and from the point of sale;
* Emissions from the home (other than electricity for fridge); and
* Treatment of wastewater as a result of drinking the beer.

**8.1 DATA AND METHODOLOGY**

No detailed studies exist of energy use of small and medium enterprises (SMEs) such as shops in the UK. The data in this section was supplied by retailers of the Kernel beer in London – Clapton Craft and the Bottle Apostle.

**8.1.1 General assumptions**

According to the brewery, of each functional unit (200 beers) an estimated:

* 100 beers are sold through pubs and restaurants;
* 100 are sold through small shops, such as off licenses. Based on information provided by the shops in this study, an estimated:
  + 80 are sold from the shop shelf, and are assumed to be taken home for domestic refrigeration; and
  + 20 are sold from the beer refrigeration unit in the shop and assumed to be consumed as they are, without being taken home and stored in the fridge.

**8.2 SHOPS (100 BOTTLES) (1.55kgCO2e)**

Gas and electricity use for the shops was worked out as shown in table 70 below.

|  |  |  |
| --- | --- | --- |
|  | **Bottle Apostle** | **Clapton Craft** |
| Number 500ml bottles sold per day | 70 | 13 |
| Number days required to sell 100 bottles | 1.4 | 8 |
| % sales that are 500ml bottles | 5% | 6% |
| **Therefore...** | | |
| % shop required to sell 100 bottles in one day | 7.14% | 48% |
| **Electricity use** | | |
| Electricity use (kWh) per day (whole shop) | 37.4 | 7 |
| Electricity use (kWh) per day for % shop required | 2.67 | 3.36 |
| Emission Factor (DECC/Defra 2013) | 0.46002 | 0.46002 |
| Electricity emissions (kgCO2e/100 bottles) | 1.23 | 1.55 |
| **Gas use** | | |
| Gas use (kWh) per day (whole shop) | 12.3 | 0 |
| Gas use (kWh) per day for % shop required | 0.88 | 0 |
| Emission Factor (DECC/Defra 2013) | 0.18404 | - |
| Gas emissions (kgCO2e/100 bottles) | 0.16 | 0.00 |
| **TOTAL EMISSIONS (KGCO2E/100 bottles)** | **1.39** | **1.55** |

Table 70: Estimations for gas and electricity use per day for small shops (based on information supplied by retailers which is highlighted in green). Note Clapton Craft uses only electricity (not gas) at the shop.

An average of the estimates of the two shops for electricity per functional unit is 1.39kgCO2e/100 bottles. The gas use estimate from Bottle Apostle is used (Clapton Craft does not use gas), which is 0.16kgCO2e/100 bottles. The total emissions for shops per functional unit are therefore 1.55kgCO2e.

The shops were not able to provide electricity use data specifically for the refrigeration units. The emissions specifically for refrigerating bottles could therefore not be calculated, but refrigeration emissions are included in the electricity usage of the shops.

It should be noted here that, although the Bottle Apostle uses more electricity than Clapton Craft, it sells each functional unit faster. So the energy required for each sale at Bottle Apostle is actually lower than at Clapton Craft.

**8.3 PUBS AND RESTAURANTS**

No pubs or restaurants were forthcoming with data, and no secondary data was available that would be suitable for this study, so it is assumed that emissions per functional unit are the same for shops as for restaurants – 1.55kgCO2e/functional unit.

**8.4 DOMESTIC REFRIGERATION (1.45kgCO2e)**

Table 71 below shows the assumptions used and their source.

|  |  |  |
| --- | --- | --- |
| **Assumption** | **Amount** | **Source** |
| All bottles sold at ambient temperature (80 of each FU) will be refrigerated in a domestic refrigerator | 80 | Estimated by author and brewery |
| Number of bottles that could fit in a domestic refrigerator | 40 | Estimated by author |
| Number of days each beer would be cooled in domestic refrigerator | 2 | Industry guidance (BIER 2014) |
| Therefore total number of days for whole fridge to cool 80 beers | 4 | n/a |
| Electricity use per day by domestic fridge (average of A spec and A++ spec) | 0.84kWh | (Carbon Footprinting 2013) |
| Energy used for domestic cooling for 80 beers | 3.36kWh | n/a |

Table 71: Assumptions for domestic refrigeration

**8.4.1 Emissions calculation**

Table 72 below shows the calculation of emissions from domestic cooling of the beer.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Number of days required for cooling 80 beers** | **Electricity use per day for fridge (kWh)** | **Electricity use per FU (kWh) (80 bottles)** | **Emission Factor** | **EF source** | **Total emissions (kgCO2e/FU)** |
| 4 | 0.84 | 3.36 | 0.4455 | DECC/Defra 2013 | 1.45 |

Table 72: Emissions calculation for domestic refrigeration

**8.5 EMISSIONS CALCULATION**

Total emissions for the retail and use stage are calculated in table 73 below.

|  |  |
| --- | --- |
|  | **Emissions (kgCO2e) per FU** |
| Shops | 1.55 |
| Pubs and restaurants | 1.55 |
| Domestic refrigeration | 1.45 |
| **TOTAL** | **4.55** |

Table 73: Total emissions calculation for retail and use stage

**8.5 DISCUSSION**

Retail and use is lower for the Kernel than New Belgium brewery. This is likely to be due to the following reasons:

* The Kernel does not sell to supermarkets, which have less energy-efficient refrigeration systems (approximately 30% more emissions) (TCC 2008) and higher rates of fugitive refrigerant emissions and leakages (7 times higher) (IPCC 2006; TCC 2008);
* A larger percentage of the beer sold through shops is not refrigerated at the point of sale for the Kernel compared to New Belgium study; and
* Shops estimate one functional unit of Kernel Pale Ale is sold in approximately one day, compared to one week for the New Belgium beer, so the Kernel beer requires less in store refrigeration time.

The Kernel emissions for retail and use are slightly higher than the European average in the BIER study (2011). The assumptions used in the BIER study regarding the number of beers that are cooled at the point of sale are not given, but it does state that the factors that influence the cooling emissions are the number of beers cooled, the temperature they are cooled to and the storage duration (BIER 2011). It could therefore be assumed that either the number of beers cooled or the storage duration (or both) are lower in the BIER study than in this study.

**9. WASTE DISPOSAL (1.88kgCO2e)**

After the beer has been consumed, some of the materials (beer packaging and transit packaging) are recycled, and may even be used again to produce more packaging materials. The remainder will be sent to landfill. Emissions from the transportation of the packaging and transit packaging materials to the recycling plant / landfill site and the processing of the recycled materials are included in this stage.

Figure 22 illustrates the process flow for the waste disposal stage, from the collection of waste after retail and use, up until its disposal at landfill, or recycling / reuse.

RETAIL AND USE

RECYCLING PLANT

PACKAGING

LANDFILL SITE

WOOD PALLET

BREWERY

Figure 22: Process flow for retail and use

* **Yellow = included process**
* **Grey = excluded process**
* **Pink = previous stage, retail and use stage**
* **Orange = recycling and reuse of packaging materials**
* **Blue = brewery stage**

**Exclusions**

Waste disposal treatment for the steel caps and pallets are accounted for in chapter 5 on packaging, because they could not be separated from the emission factor for the production of the packaging. They are therefore excluded from this stage.

**9.1 DATA AND METHODOLOGY**

UK Government GHG conversion factors (DECC/Defra 2013) are used for recycling rates for the packaging materials. These are applied to the total waste produced of each material, to give estimates of the amount of waste recycled. The amount of waste sent to landfill is calculated by subtracting the estimated waste recycled from the total waste produced.

**9.2 ALLOCATION PER FUNCTIONAL UNIT**

Calculations of the weight of packaging per functional unit by material type are shown in table 74 below.

|  |  |  |  |
| --- | --- | --- | --- |
| **PACKAGING TYPE** | **Quantity / FU** | **Weight each (kg)** | **Weight (kg/ FU)** |
|
| **Glass bottles** | 200 | 0.3 | 60 |
| **Paper labels** | 200 | 0.0017 | 0.33 |
| **Pallet wrap** | 0.2 | 2.23 | 0.45 |
| **Cardboard boxes** | 16.67 | 0.23 | 3.81 |

Table 74: Calculations of packaging weight per functional unit (FU)

**9.3 EMISSIONS CALCULATION**

Estimated emissions from recycling the packaging materials are shown in table 75 below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **PACKAGING TYPE** | **Weight  (kg/FU)** | **UK Recycling rate 2010 (DECC/Defra 2013) %** | **Total recycled (kg/ FU)** | **Emission factor(/kg) (DECC/Defra 2013)** | **Recycling emissions (kgCO2e/FU)** |
|
| Glass bottles | 60 | 60.74 | 36.45 | 0.021 | 0.77 |
| Paper labels | 0.33 | 81.85 | 0.27 | 0.021 | 0.01 |
| Cardboard boxes | 3.81 | 81.85 | 3.11 | 0.021 | 0.07 |
| Pallet wrap | 0.45 | 24.14 | 0.11 | 0.021 | 0.00 |
| **TOTAL** |  |  |  |  | **0.84** |

Table 75: Emissions from recycling of the packaging per functional unit (FU)

Emissions from packaging materials sent to landfill are shown in table 76 below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **PACKAGING TYPE** | **Weight  (kg/FU)** | **Total recycled (kg/ FU)** | **Total assumed sent to landfill (kg/FU)** | **Landfill emission factor (/kg) (DECC/Defra 2013)** | **Landfill emissions (kgCO2e/kg)** |
|
| Glass bottles | 60 | 36.45 | 23.55 | 0.026 | 0.61 |
| Paper labels | 0.33 | 0.27 | 0.06 | 0.553 | 0.03 |
| Cardboard boxes | 3.81 | 3.11 | 0.69 | 0.553 | 0.38 |
| Pallet wrap | 0.45 | 0.11 | 0.34 | 0.034 | 0.01 |
| **TOTAL** |  |  |  |  | **1.04** |

Table 76: Emissions from packaging waste sent to landfill per functional unit (FU)

Total emissions are summarised in table 77 below.

|  |  |  |  |
| --- | --- | --- | --- |
| **PACKAGING TYPE** | **Recycling emissions (kgCO2e/FU)** | **Landfill emissions (kgCO2e/kg)** | **Total waste emissions (kgCO2e/FU)** |
|
| Glass bottles | 0.77 | 0.61 | 1.38 |
| Paper labels | 0.01 | 0.03 | 0.04 |
| Cardboard boxes | 0.07 | 0.38 | 0.45 |
| Pallet wrap | 0.00 | 0.01 | 0.01 |
| **TOTAL** | **0.84** | **1.04** | **1.88** |

Table 77: Calculations of total waste disposal emissions calculation per functional unit (FU)

**9.4 DISCUSSION**

Emission factors in table 76 from sending non-biodegradable wastes (glass, plastic, steel) to landfill are low (compared to recycling emission factors in table 75) because no carbon will be released from the material, and transportation and processing emissions from landfill sites are minor (BSI 2011b). For materials that are recycled, there are processing emissions involved (BSI 2011). However there are many benefits to recycling materials, as explained in the section 5.5.2 on the emissions reductions from manufacturing when using recycled glass compared to processing raw materials. The benefits of using recycled content are accounted for in chapter 5 on packaging production, and are therefore not double-counted here.

1. **CONCLUSION**

**10.1 FINDINGS OF THE CARBON FOOTPRINT ASSESSMENT**

The total emissions from the whole life of the beer are 73.68kgCO2e per functional unit. This is equivalent to 368gCO2e per individual 500ml bottle of Pale Ale.

Table 78 below summarises the emissions from each stage, in order of percentage contribution to the overall footprint.

|  |  |  |
| --- | --- | --- |
| PACKAGING | 44.38 | 60% |
| BREWING | 7.74 | 11% |
| MALTING | 6.97 | 9% |
| RETAIL AND USE | 4.55 | 6% |
| BARLEY PRODUCTION | 4.37 | 6% |
| DISTRIBUTION | 3.02 | 4% |
| WASTE DISPOSAL | 1.88 | 3% |
| HOPS PRODUCTION | 0.77 | 1% |
| **TOTAL FOOTPRINT/HL** | **73.68** |  |

Table 78: Emissions by stage

If the production of the barley and malt are added together as ‘the production of the malt’, emissions would be 11.34kgCO2e, and it would be the stage with the second highest emissions in the life of the beer.

Figure 23 illustrates the amount of emissions by stage over the life of the beer.

Figure 23: Comparison of emissions from different life cycle stages

**10.1.1 Emissions hotspots**

As with many other studies (Koroneos et al. 2003; Talve 2001; TCC 2008), in terms of climate change impact, the most significant life cycle stages for the Kernel beer are:

* The production of the glass bottle (which is responsible for over half the total emissions);
* Brewing and malting (which are both responsible for similar amounts of emissions); and
* Barley production.

Most studies (Koroneos et al. 2003; Talve 2001; TCC 2008) also found distribution, and retail and use stages to be responsible for a large share of emissions. However for the Kernel, these were not as significant. As explained in chapters 7 and 8, this is mostly due to the Kernel’s focus on local distribution, direct sales where possible (thus minimising emissions from distribution transportation) and not selling through supermarkets (which tend to have more emissions associated with the sale of each beer than a small shop).

**10.1.2 Emissions coldspots**

* Distribution emissions are only responsible for 5% of total emissions – far lower than other studies due to the brewery’s emphasis on local, sustainable distribution, and where possible, direct sales to the customers (which have zero emissions);
* Retail and use emissions are only 7% of the overall footprint, due in part to beer being sold mostly through small shops rather than supermarkets;
* Despite the fact that the hops are imported from around the world, their impact is still negligible (around 1%); and
* Waste disposal.

**10.1.3 Critical analysis of the evidence presented in this study**

*10.1.3.1 Uncertainties*

A critical analysis of the evidence gathered in this study is presented in table 79 opposite.

As shown in the uncertainty analysis:

* The largest uncertainty is with the glass bottle production emissions. The recycled content of the specific bottle used is unknown. In this study the UK average of 20% recycled content for amber bottles is used. However if the 47% recycled content rate is used (which is used in the O-I data supplied), the emissions per functional unit would be decreased by 4.82kgCO2e, which is a 7% decrease in the total emissions for the whole life of the beer.
* There is also uncertainty regarding the yield for the barley. 6.5 tonnes/ha is used in this study, but the range of likely yields is between 6 and 7 tonnes/ha. The uncertainty range for barley cultivation per functional unit is shown to be +/- 0.32kgCO2e in section 10.2.5. However this equates to only a 0.004% difference compared to the figure used in this study for 6.5 tonnes/ha.

There are many other uncertainties which are listed in table 75 above, in particular the retail and use stage. However analyses are only performed on uncertainties for stages which are shown to be significant (i.e. over 5% of the total footprint[[14]](#footnote-14)) and where information was available.

*10.1.3.2 Completeness*

There are several elements that were excluded from this study because they were classified as *de minimus* sources (see appendix A), which means they contribute less than 1% of the total emissions. When added together, these *de minimus* sources come to under 0.01% of the emissions so they are therefore judged to be negligible.

Where emissions estimates were not available (such as for effluent treatment or yeast), these elements were excluded. These gaps in knowledge have been noted in table 75 as areas for further research. However over one hundred elements have been included in this study, in comparison to only three excluded elements due to a lack of information, so this study can be judged to be reasonably complete.

*10.1.3.3 Conclusion*

As shown in this critical analysis of the evidence, the study is judged to be completed to a high level (only a few omissions due to lack of data), and the data is all moderate or good.

**10.2 HOW THE CARBON FOOTPRINT COULD BE REDUCED**

Suggestions of how the carbon footprint could be reduced are discussed below and focus on the emissions hotspots identified above.

**10.2.1 Changing glass colour (approx 10kgCO2e/hl)**

As explained in section 5.5.2, the higher the recycled content of glass, the lower the emissions. The average UK recycled content of green glass is 80% compared to 20% for amber glass (British Glass 2014).

As shown in table 80 below, emissions savings of up to 10.25kgCO2e/hl could therefore be achieved by using green glass instead of amber. If the total footprint of the beer is 71.27kgCO2e/FU, this would represent a 14% decrease in total emissions.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **AMBER GLASS EMISSIONS (20% RECYCLED CONTENT)** | | **GREEN GLASS EMISSIONS (80% RECYCLED CONTENT)** | |
| **kgCO2e/kg glass** | **kgCO2e/hl** | **kgCO2e/kg glass** | **kgCO2e/hl** |
| CO2e Reduction from Recycling | -0.06 | -3.59 | -0.23 | -13.87 |
| **TOTAL** | **0.623** | **37.59** | **0.45** | **27.34** |

Table 80: Comparison of emissions savings from recycling for amber and green glass (based on O-I data)

However the brewery does have some concerns regarding green glass. Light can affect the flavour of the beer, turning it ‘skunky’ (a sour-lime smell). Amber glass absorbs light and therefore protects the beer, whereas green glass does not. If the brewery preferred not to use green glass, an amber bottle with a higher than average recycled content could be sought.

**10.2.2 Reusable bottle (up to 10kgCO2e)**

The carbon footprint of a beer can be reduced by using returnable bottles instead of disposable bottles (BIER 2011). Although returnable bottles tend to be heavier (which would probably involve larger transportation emissions and more raw materials per bottle), production emissions are avoided each time it is reused, reducing the footprint of the bottle considerably (BIER 2011).

There are logistical issues with returnable bottles. They must be cleaned by a special machine which the brewery does not own and are very expensive. However some shops, such as Clapton Craft – a craft beer and growler (refillable bottle) refill shop – already have the equipment. Other shops such as Borough Wines – who already offer a refillable wine bottle service and are a key retailer of the Kernel’s bottled beer – could perhaps be persuaded to offer a refillable beer bottle service.



Figure 24: Refillable bottle (Warner Music Group website)

Many beer drinkers under the age of 40 will never have used returnable beer bottles, because they have not been in use in the UK for many years (BBPA 2013). For customers to start reusing beer bottles would require a culture change in the way beer is sold and consumed. However, unless the option to use reusable bottles is given to consumers, a change to a more sustainable way of consumption will not be able to take place.

**10.2.3 Renewable energy (up to approximately 2kgCO2e)**

As shown in section 6.3, breweries such as New Belgium Brewery which use renewable energy with zero emissions for electricity can have a very low footprint for the brewery stage (approximately 5.8kgCO2e/functional unit for New Belgium compared to the Kernel’s 7.63kgCO2e/functional unit).

Renewable energy micro systems have been shown to be unsuitable for small buildings in cities (Clark 2013). Neither wind nor solar energy would be viable for a brewery located under a railway arch. If emissions were to be reduced at the brewery, reducing energy use or switching to a renewable energy tariff would be the best strategy.

**10.2.4 Lower emission distribution transport (reduction of 0.09kgCO2e)**

London distribution is responsible for 0.47kgCO2e per functional unit – 0.66% of the overall emissions. Could using electric vehicles result in lower distribution emissions?

Research has shown that electric vehicles offer savings of around 20% compared to standard gasoline vehicles over the lifetime of the vehicle (Ricardo 2011). This takes into consideration the emissions from the production of the vehicle (which are higher for electric than standard gasoline vehicles), which, it should be noted, are not included in the emission factors used in chapter 7 on distribution (because they are scope 3).

If using electric vehicles could result in savings of 20% of emissions, this would be equivalent to 0.09kgCO2e per functional unit for London deliveries.

**10.2.5 Other packaging options**

Using alternative packaging types (e.g. kegs or cans instead of glass) could potentially reduce the footprint. Due to the time limitations of this study, this was not investigated in this report. However this will be investigated further as a follow-up to this study.

**10.2.6 Barley cultivation (0.64kgCO2e)**

Two factors were shown in chapter 2 to have a significant impact on the emissions from the barley cultivation stage – fertiliser use and yield. The two are often linked – fertiliser use can lead to higher yields (Garnett 2007) – but if a type of barley can be found that can have a higher than average yield and lower than average use of fertiliser, emissions could potentially be reduced.

Based on the range of typical yields for Maris Otter barley given in an industry article (Jones 2010), a sensitivity analysis was performed in order to evaluate the impact of the yield per hectare of barley on the emissions per hectolitre.

|  |  |  |  |
| --- | --- | --- | --- |
| **Yield/ha** | **%ha/hl** | **Emissions/ha (kgCO2e)** | **Emissions/hl (kgCO2e)** |
| 6,000 | 0.0042 | 1063.90 | 4.47 |
| 6,500 | 0.0039 | 1063.90 | 4.15 |
| 7,000 | 0.0036 | 1063.90 | 3.83 |

Table 81: Sensitivity analysis of yield per hectare

The difference between the yield for 6 tonnes/ha and 7 tonnes/ha is 0.64kgCO2e/hl. The uncertainty range for the 6.5 tonnes/ha estimate used in this study is therefore +/- 0.32. A high yield of 7tonnes/ha can therefore be said to have a 13% impact on the emissions from the cultivation of the barley, and around 0.9% impact on the overall footprint of the beer.

However, without having data relating specifically to the cultivation of Maris Otter barley, it is not possible to evaluate whether using another type of barley would save emissions.

**10.2.7 Conclusion**

If all the reduction opportunities listed above were actioned, the total footprint of the functional unit could be reduced by 17.28%, as calculated in table 82 below.

|  |  |
| --- | --- |
| **Action** | **Savings of up to (kgCO2e)** |
| Switch glass colour or to reusable bottles | 10 |
| Green energy | 2 |
| Lower emission transport for London | 0.09 |
| Higher yielding and lower fertiliser use barley used | 0.64 |
| **TOTAL** | **12.73** |
| **Current carbon footprint** | **73.68** |
| **Potential % saving of total footprint** | **17.28%** |

Table 82: Calculation of potential carbon footprint reduction

From the sensitivity analyses undertaken in this section, it is clear that the element of the life cycle of the beer that has the biggest potential for emissions savings is the packaging.

**10.3 WHAT WILL NOT RESULT IN SIGNIFICANT EMISSIONS SAVINGS**

**10.3.1 Importing hops from Europe rather than the New World**

The emissions from importing hops (transportation emissions only) from different countries were estimated in order to understand whether emissions could be saved by importing hops a shorter distance (i.e. Europe rather than the New World).

In order to make a fair comparison, emissions from importing the total amount of hops per functional unit (0.834kg) from each country (USA, Germany and Australia) were calculated in table 83 and compared in figure 25 below. New Zealand was not calculated in this analysis, because the distance and method of transport is similar to Australia. These calculations used the same emission factors and assumptions listed in chapter 3.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **TRANSPORT** | | **TONNE.KM CALCULATION** | | | **EMISSIONS CALCULATION** | | |
| **Journey** | **From... to** | **Vehicle type** | **Distance (km)** | **FU freight weight (tonne)** | **Tonne.km** | **Tonne.Km Emission factor** | **Emissions (kgCO2e/tonne)** | **Total emissions (kgCO2e/tonne)** |
| USA hops to Brewery | Sunnyside to Seattle | HGV | 284.85 | 0.000834 | 0.24 | 0.2075 | 0.05 | 0.30 |
| Seattle to Montreal | Train | 4692.85 | 3.91 | 0.0363 | 0.14 |
| Montreal to Antwerp | Ship | 4997.01 | 4.17 | 0.0031 | 0.01 |
| Antwerp to Herstal (warehouse) | HGV | 119 | 0.10 | 0.2075 | 0.02 |
| Herstal to brewery (excl Dover Calais) | HGV | 433 | 0.36 | 0.2075 | 0.07 |
| Calais to Dover | Train | 33.80 | 0.03 | 0.0096 | 0.0003 |
| German hops to Brewery | Assumed Nuremberg to Calais | HGV | 814.33 | 0.000834 | 0.68 | 0.2075 | 0.14 | 0.16 |
| Calais to Dover | Ro-ro ferry | 33.8 | 0.03 | 0.0096 | 0.0003 |
| Dover to Bermondsey | HGV | 119.09 | 0.1 | 0.2075 | 0.02 |
| Australian hops to Brewery | Bushy Park to Hobart | HGV | 50 | 0.000834 | 0.04 | 0.2075 | 0.01 | 0.09 |
| Hobart to Southampton | Ship | 20956.88 | 17.48 | 0.0031 | 0.05 |
| Southampton to Bermondsey | HGV | 128.91 | 0.11 | 0.2075 | 0.02 |

Table 83: Calculations of emissions from transporting the hops for one FU from different countries

Figure 25: Comparison of emissions from transporting all hops for one functional unit from different countries (kgCO2e/FU)

Imported Australian hops (which travel the furthest in terms of distance), have almost half the transportation emissions of the German hops, and just over a quarter of the transportation emissions of the USA hops. This is due to the majority of the transport being marine, which is low emission compared to road and rail transport used by the USA and German hops.

From this analysis it can be concluded that when considering the climate change impact of importing hops, the mode of transport can have more of an influence than the distance travelled. If the information is available, the relative emissions of cultivating the hops should be taken into consideration. However in this study they were only available for the hops from the USA. It should also be noted that the transportation of hops was shown to be responsible for a negligible amount of emissions – less than 1% of the footprint of the beer.

**10.4 FURTHER RESEARCH OPPORTUNITIES**

Following on from a presentation of the findings to the brewery owner, the following areas have been identified for further research by the brewery owner:

* The impact of using a reusable bottle, and how this could work in practice (i.e. joining up with other local breweries to make it more cost-effective);
* Using a glass bottle with higher recycled content (green glass may not be practical due to light issues, but there may be companies that produce amber glass bottles with higher recycled content);
* Investigate and compare the impact of using different packaging types, such as reusable keg, disposable keg, cans; and
* Using an electric vehicle for London distribution transport.

The brewery owner has also asked for the presentation of findings to be made to all staff at the brewery, to increase awareness of the climate change impact of the beer amongst all staff.

Additional gaps in knowledge, such as the emissions from yeast, have been indentified in table 75 of this study.

**APPENDIX A – DE MINIMUS SOURCES**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **QUANTITY** | | **EMISSION FACTOR (EF)** | | **EMISSIONS** | |
| **Quantity per HL** | **Unit** | **EF** | **EF source** | **per FU** | **% of overall footprint** |
| **BARLEY CULTIVATION** |  |  |  |  |  |  |
| Insecticides | 0.00006 | kg | 5.1 | Lal 2004 | 0.0003 | 4.26633E-06 |
| Water | 0.000017 | % of ha | 239 | West and Marland 2001 | 0.004 | 5.69606E-05 |
| Waste | 5 | kg/ha | 0.034 | Defra 2013 | 0.17 | 0.002 |
| **MALTING** |  |  |  |  |  |  |
| Kerosene | 0.01 | kWh | 0.2467 | Decc/Defra 2012 | 0.004 | 5.11831E-05 |
| Diesel oil | 0.01 | kWh | 0.2721 | Decc/Defra 2012 | 0.004 | 5.64635E-05 |
| Waste | 5 | kg/ha | 0.034 | Defra 2013 | 0.17 | 0.002 |
| Compost | 15.43 | short ton | 0.0002 | EPA (2012) | 0.003 | 4.32702E-05 |
| **BREWING** |  |  |  |  |  |  |
| Sugar | 0.35 | kg | 0.3 | Tate and Lyle 2013 | 0.11 | 0.001 |
|  |  |  |  |  |  |  |
| **Total footprint** |  |  |  |  | **71.27** |  |
| **Total % of overall footprint** |  |  |  |  |  | **0.006** |

Table 84*: De minimus* source calculations

**APPENDIX B – TRANSPORT EMISSIONS CALCULATIONS**

Table 85: Transport emissions calculations

**APPENDIX C – EMISSION FACTORS**

Emission factors used in multiple sections of this carbon footprint assessment are explained in this appendix.

**Energy**

As recommended in carbon footprinting guidance (BSI 2011), the UK government conversion factors are used in this study ([www.ukconversionfactorscarbonsmart.co.uk](http://www.ukconversionfactorscarbonsmart.co.uk)). The emissions for fuels and electricity include both indirect (production and distribution (factoring in distribution losses for electricity) and direct (point of use) emissions. It should be noted that emission factors for electricity in the UK have only recently started to include the generation and transmission and distribution stages, so these figures may be higher than in previous studies.

Since the majority of the barley and hops would have been cultivated the year before they are used in brewing, emission factors for 2012 are used for cultivation, and 2013 for malting, brewing, retail and use.

Defra emission factors for energy used in this study are shown in table 86 for 2012 and table 87 for 2013.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **2012 Emission Factor (EF)** | | |
|  | **EF** | **Per** | **Source** |
| Electricity | 0.46002 | kgCO2e/kWh | DECC/Defra 2012 |
| LPG | 1.5326 | kgCO2e/litre | DECC/Defra 2012 |
| Kerosene (Burning Oil) | 2.5443 | kgCO2e/litre | DECC/Defra 2012 |
| Diesel | 3.427 | kgCO2e/kg | DECC/Defra 2012 |

Table 86: Emission factors for energy for 2012

|  |  |  |  |
| --- | --- | --- | --- |
|  | **2013 Emission Factor (EF)** | | |
|  | **EF** | **Per** | **Source** |
| Electricity | 0.44548 | kgCO2e/kWh | DECC/Defra 2013 |
| Gas (m3) | 2.0196 | kgCO2e/m3 | DECC/Defra 2013 |
| Gas (kWh) | 0.18521 | kgCO2e/kWh | DECC/Defra 2013 |

Table 87: Emission factors for energy for 2013

**Water**

For water and waste water in the brewing operations stage, the conversion factor for Thames Water – the brewery’s supplier – is used. Thames Water’s CO2e emission factors include emissions from:

* Activities which directly involve burning fossil fuels (natural gas and company vehicle transport emissions);
* Activities which use electricity (treating and pumping water);
* Carbon associated with the sewage sludge produced at the sewage treatment works;
* Business travel and private vehicles used for company business; and
* Outsourced activities undertaken for Thames Water which involve the above (personal communication Kai Ebury, Thames Water, April 2014).

Thames Water estimates emissions of 0.293kgCO2e/m3 of treated potable water (Thames Water 2014), which is slightly lower than the UK government conversion factor (DECC/Defra 2014) of 0.3441kgCO2e/m3. This could be because Thames Water generated renewable electricity in 2012 that covered 12.5% of its electricity needs.

The emission factor from Thames Water for waste water treatment is 0.266kgCO2e/m3 treated waste water.

**Transport**

The brewery does not own any vehicles, so all upstream (e.g. inbound transportation of ingredients and packaging materials) and downstream transport (distribution of the beer) is undertaken by third parties. In order not to double count emissions with the companies who own the transportation vehicles (should they decide to assess the carbon footprint of their operations), emissions from distribution transport are calculated using ‘scope 3’ emission factors (which are smaller than ‘scope 1’ emission factors from a company that owns its own transport). These are also commonly described as ‘indirect emissions’ (DECC/Defra 2014).

DECC/Defra (2012) emission factors are used to calculate the emissions from transporting the freight.

* Where fuel consumption data was available, fuel emission factors are used; and
* Where fuel data was not available, a tonne.km emission factor was used (a tonne.km is the distance travelled multiplied by the weight of the freight transported).

*Truck emission factors*

These factors from DECC/Defra (2012) are used throughout and are derived from the 2010 UK fleet average kgCO2 per vehicle, which appear to be the most recent tonne.km factors available. The emission factor for rigid HGVs with a capacity of over 17tonnes (t) was used, because all of the suppliers who responded to queries about the vehicle used to transport the goods confirmed that a 17t or over vehicle was used.

The percentage laden (the extent to which the vehicle is loaded to its maximum capacity) data was not available from suppliers. The emission factor assumes the trucks are 54% laden, which is the UK average (DECC/Defra 2012).

*Cross-channel ferry*

The emission factor for the average roll on roll off (ro ro ferry) tonne.km was used for Dover to Calais ferry journeys.

**Nitrous Oxide emissions from soils**

The International Panel on Climate Change (IPCC 2006) has produced default values for N20 emissions from soils for:

* Volatisation of 1% of the nitrogen (N) applied (the uncertainty range for volatisation is fairly high (0.002 – 0.05) (IPCC 2007)); and
* Leaching of 0.0075% (the uncertainty range is slightly lower for leaching (0.0005 - 0.025)).

The reason for the large uncertainty ranges for these emission factors is because the amount of nitrous oxide produced is influenced by many factors – the type of fertiliser used, how it is applied, number of applications, soil characteristics, climate and others.

The emission factors quoted above are from the tier 1 methodology of the IPCC guidelines – this is used when only basic activity data is available (IPCC 2006).

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1. Climate change impact is measured in terms of kilos of carbon dioxide equivalent (CO2e), which accounts for all greenhouse gases. [↑](#footnote-ref-1)
2. BIER is a partnership of global beverage companies working together on the topic of environmental sustainability. It is dominated by U.S.-based global companies such as PepsiCo and MillerCoors. [↑](#footnote-ref-2)
3. Barley used for malting is often required to have a certain plumpness and protein content which requires less nitrogenous fertiliser (Garnett 2007) and since nitrogenous fertiliser increases yields, malting barley tends to have a lower yield than non-malting barley (Agriculture and Rural Development 2009) [↑](#footnote-ref-3)
4. Winter barley tends to require more fertiliser than spring barley (Rush 2010). [↑](#footnote-ref-4)
5. The survey contains data on a sample of 512 farms, which were selected based on the June Agricultural Survey – an annual survey which records information on farm size and cropping. [↑](#footnote-ref-5)
6. Many of the hops in the TCC study (2008) were grown in the same region of the USA where the beer is brewed, so transport emissions would have been minimal. [↑](#footnote-ref-6)
7. When the barley arrives at the maltster, energy is used to reduce the moisture content of the barley to avoid spoilage during storage. Once it is required for malting, it is steeped in water for two days to reach a moisture content of 45%. It is then drained several times and warmed in a vessel for four days. This starts the germination process, during which it loses moisture of about 0.5-1% per day. While it germinates, it starts to create small rootlets which are later removed and sold as animal feed. It is then heated in a kiln for 24 hours to stop the germination and reduce the moisture to 4% – this is the most energy-intensive process of the malting stage (personal communication, Pierre-Antoine Kantor, 2014. [↑](#footnote-ref-7)
8. Data was taken from meter readings, utility bills and company records. The data provided are not specific to the type of malt used by the Kernel, but, according to Simpson Malt, average figures are believed to be representative of the energy use of the malt used by the Kernel (personal communication, Pierre-Antoine Kantor, 2014). [↑](#footnote-ref-8)
9. The Carbon Trust report (2011) uses data from five UK malting companies which together represent 28% of the UK industry. Simpsons Malt was not one of the five included in that study. [↑](#footnote-ref-9)
10. Twice as much green glass is imported into the UK – mostly from wine bottles – than is produced in the UK (WRAP 2008). [↑](#footnote-ref-10)
11. The 47% recycled content rate used in the O-I study is likely to be an average of the recycled content rates of different types of glass, potentially ranging from around 20% for amber to around 80% for green glass. [↑](#footnote-ref-11)
12. The data is from Climate Change Agreement scheme between the government and the UK brewing sector. [↑](#footnote-ref-12)
13. Some Kernel beer is also distributed to Europe, however the 500ml bottles of Pale Ale are only sold in the UK. [↑](#footnote-ref-13)
14. Due to the time limitations of this study, all uncertainties could not be analysed. If there was an uncertainty regarding an element in the life cycle that is responsible for less than 5%, the uncertainty was noted but no further action was taken. [↑](#footnote-ref-14)