Greenhouse Gas Analysis of Deya Brewing

Analysis of the greenhouse gas
emissions associated with Deya Brewing by Tyndall Sustainability

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Contents

Abstract

An environmental assessment was undertaken for the greenhouse gas (GHG) emissions at Deya Brewing in line with the GHG Protocol corporate and product standards. Scope 1, Scope 2 & Scope 3 emissions were analysed, and emissions for three individual beers, packaged in 500ml cans, were subsequently calculated. Across the three scopes 8.29% of the total emission burden for the year is associated with Scope 1, 3.35% with Scope 2 and 88.36% for Scope 3. Scope 3 emissions are split into upstream and downstream activities of which 81.59% of Scope 3 emissions relate to upstream and 18.41% to downstream. For the three products analysed: Into The Haze (ITH), Tappy Pils (TAP) & Steady Rolling Man (SRM) the Global Warming Potential (GWP) was equal to 0.38 kgCO_2e, 0.33 kgCO_2e and 0.34 kgCO_2e respectively, per 500ml can sold. If Deya Brewing beer products are to be considered carbon neutral, it is recommended that all Scopes are offset for the year 2020, equating to 639tCO_2e.

1 Introduction

An environmental assessment was undertaken to calculate the greenhouse gas (GHG) emissions for products being sold at Deya Brewing. This report aims to provide complete transparency in outlining how the results were collated to inform the readers on the possible hot spots of GHG emissions in the supply chain. The report has been conducted with reference to the GHG Protocol emissions standards [1, 2, 3]. All aspects of direct and indirect emissions have been considered and are explained within the main body of this report.

In completing this analysis Deya Brewing seeks to identify carbon hotspots for reduction and offsetting targets to be put in place. The company understands reducing their carbon footprint is needed for sustainable business practices and seeks to continue to operate in conjunction with being environmentally conscious.

1.1 Aims and Objectives

The overall aim is to complete a full GHG assessment of Deya Brewing through direct and indirect processes to allow the company to decide on emission reduction strategies in future business practices.

Best practices in reduction techniques will be highlighted in the main body of this report after the full GHG assessment results have been completed. This systematic approach to the analysis is critical in choosing the right mitigation strategies in GHG reduction.

2 Methodology

2.1 Standard Compliance

This report is based on compliance conditions with the GHG Protocol Corporate Standard and GHG Protocol Product Standard. Full transparency is provided about the sourcing of results which should be used for customer and business education. Any source which has been used in the main body of the report or appendices are referenced.

In line with the GHG Protocol Corporate Standard, Scope 1 emissions focuses on direct emissions to the environment from company operations while Scope 2 focuses on the emissions drawn for energy generation involved in the company's operations. Finally, Scope 3 emissions are intended to hold companies accountable for their wider impact on the environment, not just direct emissions from operations. Scope 3 emissions are split into upstream and downstream emissions. Upstream emissions relate to factors that are attributed to material acquisition and pre-processing whereas downstream emissions relate to distribution, storage, use and end of life. Table 1 shows an overview of the scopes and their respective activities. It was intended that all possible activities, contributing to Scope 3 emissions were accounted for, to provide the most accurate representation of Deya's total emissions.

Table 1: Highlighting the different activities including in the varying scopes.

Scope	Related Activities
1	Refrigerants Natural Gas Fermentation
2	Generation of purchased electricity
3 (Upstream)	Water Supply Water Treatment Agricultural Transport Employee Transport Capital Goods Agricultural Packaging Deya Packaging Electricity Losses Gas WTT Agricultural CTPG Liquid CO_2 Emission
3 (Downstream)	Delivery of Goods Customer Transport Material Disposal

The GHG Protocol Product Standard factors are outlined in Table 2. Three beers were analysed: Steady Rolling Man (SRM), Into The Haze (ITH) and Tappy Pills (TAP). All agricultural subsections were included in the Product Standard calculation. The calculations were then used as the basis of the Corporate Standard for agricultural inputs. Sections omitted from the Product Standard were done so due to not having reasonable emission attribution to the final products being sold and therefore would be unreasonable to aggregated into the final product emissions. During the results section, the differences between Corporate and Product Standards are made apparent.

Table 2: The boundaries of the Product Standards

Product Standard	Included Activities	Omitted Activities
Agricultural	Agricultural CTFG Agricultural Transport Agricultural Packaging Disposal Agricultural Packaging Production	N/A
Processing	Fermentation Carbonation Water Use Water Treatment Refrigerant Leakage Electricity Gas	Capital Goods
Packaging	Aluminium Cans & Lids Packaging Labels	Subsidiary Delivery Packaging Subsidiary Collection Packaging
Transportation	Delivery Transport Customer Collection	Employee Commute

2.2 System boundaries

The main system boundaries for the assessment are shown in Figure 1. This assessment focuses on a "cradle to grave" approach, with the main categories being: agricultural inputs, transport, processing, waste, delivery consumer activities. The system thus covers all of Deya Brewing's decisions that contribute to their overall GHG emissions. By using this boundary, Deya Brewing can extrapolate key areas in their supply chain and have the opportunity to adapt operations to further lower their total emissions.

Figure 1 shows the subheadings in green, which relate to the overarching headings in black. It should be noted that all upstream agricultural activities are considered under the agricultural phase of analysis.

Excluded from the analysis were items sold other than beer from Deya Brewing, who sell a comparatively small amount of subsidiary items including branded clothing and drinking glasses compared to beer. Also excluded was the office related equipment.

2.3 Data Collection and Uncertainty

Deya provided records of all data necessary for the completion of the analysis. Data inventories were reviewed to determine quantities and sourcing locations of aspects relating to agricultural inputs, transport, processing, waste, delivery and consumer activities. Where data had not already been collected or needed further detail, questionnaires were conducted on customer activities and suppliers were contacted directly for information. Since operations have been scaled in 2020, the old premises are still currently operational. To account for the excess GHG emissions arising for the old premises, physical allocation was conducted by output of product, to scale the affected processing parameters.

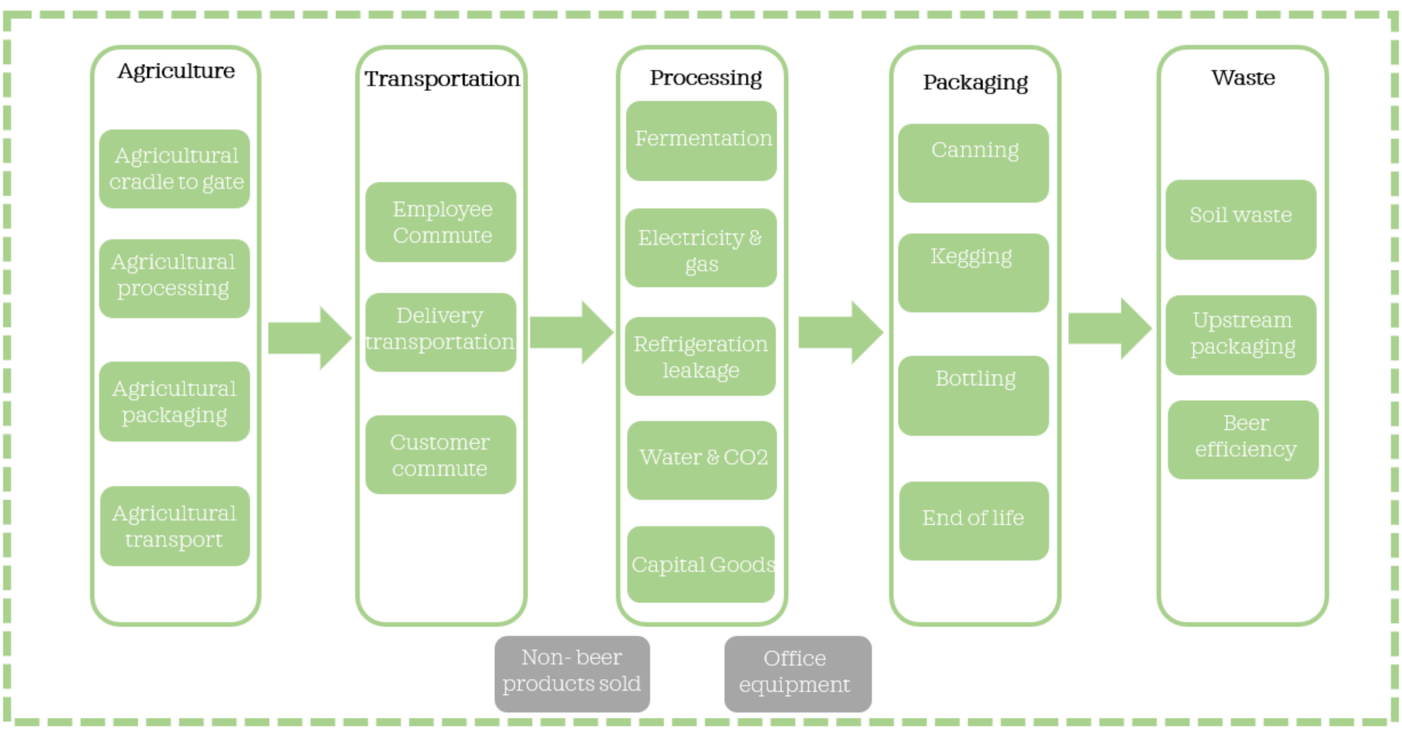

Figure 1: The system boundaries for analysis at Deya Brewing.

Corresponding emission data in this paper was collected from various published sources. A full breakdown of sources are detailed in the supplementary data, linked at the end of this report. The vast majority of data was gathered from life cycle assessments (LCAs), specific to individual products. LCAs are seen as one of the most accurate ways of analysing the environmental burden of specific products. LCAs sources are conducted, in the vast number of cases, with the same methodology based on the guidance outlined in the ISO 14044/14040. However input data can vary, affecting the transferability and comparability of certain sources. To account for this, each source has been reviewed to determine the quality and applicability of input methods. Where necessary, sources have been modified to account for updated figures, with further detail being seen in future sections of this report. To obtain accurate data, the most up to date papers from reliable sources were used for each aspect. When there was no exact data existing on a certain topic, estimates have been assumed and recorded. Any uncertainties that were qualitatively thought to be significant were then subjected to the sensitivity analysis in this report.

All quantity output data was collected from data relating to September 2020. The subsequent yearly values were scaled from the September measurements due to this month being a more accurate representation moving forward compared to previous months due to the COVID-19 Pandemic impacting on output.

2.4 Impact Factors

Many sources referenced in this paper include multiple impact categories to try to evaluate the whole environmental burden of a specific item. In line with the GHG Protocol standards, the scope of this assessment is limited to global warming potential (GWP) which is measured as a function of carbon dioxide equivalent (CO_2e). This impact category uses the global warming potential of CO_2 as a reference value and analyses gases environmental impact over a 100 year period. The GHG gases considered included: CO_2, CH_4, N_2O, HFCs, PFCs and SF_6, where all GWP were related to the IPCC Fifth assessment report. Table 3, highlights the different conversion factors for the three main GHG as recorded in the IPCC Fifth assessment report [4].

Table 3: An overview of the most common greenhouse gases and their global warming potentials.

Greenhouse Gas	Notation	Global Warming Potential
Methane	CH_4	28
Nitrous Oxide	N_2O	265
Carbon Dioxide	CO_2	1

2.5 Functional Unit

The assessment was conducted with litre (L) of sold product as the functional unit. An estimate was taken as the density of beer to be 1kg/m3. This functional unit was used to normalise different papers to achieve an overall $kgCO_2e/L$ for each product to enable ease of comparison. Equating different functional units were gathered from sources on yield values, moisture content and densities. Adjustment of the functional unit may be necessary for Deya's use, to help with ease of customer visualisation therefore it is recommended that a reasonable in-house functional unit is $kgCO_2e/500ml$ beer, as demonstrated in the results section. For total cumulative emissions (Scope 1, 2 & 3) the unit of analysis has been shown as $kgCO_2e$.

2.6 Transport

Origins of products were sourced and freighting methods were estimated from major origin ports to the UK and subsequently to Deya Brewing. The three major methods analysed were a diesel articulated non refrigerated HGV with carrying load of over 33 tonnes, an average cargo ship and an average van. None of the products analysed have been assumed air-freighted due to their shelf life, allowing for sea or road shipping methods. Maximum van transport distances were assumed to be 150km due to region distribution networks throughout the UK.

Delivery methods for Deya Brewing have been analysed in line with how the customers receives deliveries. One option is customers can pick up directly from the brewery's tap room. For this method a sample of 40 customers completed a questionnaire in regards to distance travelled, party size and mode of transport. The results were scaled from the percentage breakdown of tap room sales, with an average order size of ten can beers presumed. The large majority of those surveyed were local to the brewery. Where this was the case the journey was assumed solely for purchase therefore doubling the one way distance journey. For journeys over 15km it was assumed the customer was on route to a separate location, therefore a detour distance from M5 junction 11 to Deya and back was assumed.

Online sale distances were calculated from Deya Brewing to the location of sales. 573 different locations around the UK were analysed and an average of 189.85km was determined by weighting with regards to the number of sales to each location.

Employee transportation methods and distances assessed through a questionnaire detailing: mode of primary and secondary transport, vehicle type, distances and frequencies. All employees were considered and an average of 5 days a week was assumed unless otherwise stated. The UK government entitles employees to a minimum of 5.6 weeks paid holiday per annum, therefore the results were weighted accordingly to a 46.4 week work year. Business travel was omitted from this report due to the magnitude being negligible for yearly statistics.

2.7 Agricultural Inputs

Ingredients lists were gathered for three beers: SRM, ITH & TAP. Specifically, these products were selected to sample as they are all different beer styles, commonly brewed and have a large market share of company sales. Average values were then scaled in relation to total sellable beer volume to determine GHG emissions from ingredients. By weight across the three products 99.8% of the ingredients were analysed, the ingredients that were omitted from the study were done so due to the lack of GHG emission data available. Subsequently all emissions relating to the agricultural GHG emissions were scaled to 100%.

Papers collected in our study assess a number of sources of emissions from farming. These can be broken down into:

- **Synthetic Fertilizers and Lime**
  Greenhouse gas emissions associated with fertilizer production vary according to different processing technologies and energy sources. Most analysis includes emissions from three primary nutrients (N, P and K) . CO_2 emissions during the production of these inputs result from the energy required for production and transport.

- **Production of pesticides**
  In order to control weeds, pests and diseases, farmers apply chemicals such as herbicides, fungicides, and insecticides to crops. GHG emissions are released during the manufacture of pesticides, which includes the formulation, packaging and transportation.

- **Production and maintenance of farm machinery and equipment**
  Greenhouse gas emissions from the use of machinery and equipment for crop production can be categorised into direct and indirect emissions. The direct emissions related to feed crops are caused by the burning of fossil fuel during field operations and the indirect emissions arise from the manufacture of farm machinery, amortisation and maintenance of the machines.

- **Land use change**
  Soils are an important part of the carbon cycle and changes in soil carbon can influence GHG emissions. GHG emissions can result from soil carbon losses caused by land use changes (LUC).

- **On-farm machinery use for field operations**
  Agricultural machinery can be employed in a number of field activities such as soil management, fertilization, harvesting, irrigation, etc. On-farm emissions associated with the use of fossil fuel use for field operations will vary by cropping practice, scale of production, level of mechanisation and type of machinery used.

- **Abstraction of ground water for irrigation**
  The direct energy inputs are primarily used to operate farm machinery and pumps, while indirect energy inputs refer to energy used to produce equipment and other goods and services used on-farm. Where groundwater is used, more energy is required for pumping. The energy required for pumping depends on the crop water requirement, total head, flow rate and system efficiency.

- **Application of agricultural lime**
  Agricultural lime is commonly used in the management of croplands and grasslands to decrease soil acidity. Lime is often applied in the form of crushed limestone ($CaCO_3$) or crushed dolomite ($CaMg(CO_3)2$). Adding carbonates to soils in the form of lime or dolomite leads to CO_2 emissions as the carbonate limes dissolve and release bicarbonate ($2HCO_3$), which breaks down into CO_2 and water

- **Nitrous oxide emissions from soils**
  In most soils, an increase in available nitrogen enhances nitrification and denitrification rates, which then increases the production of N_2O, along with indirect emissions from leaching and volatilization. The main sources of N_2O included in the methodology for estimating N_2O emissions from soils include synthetic nitrogen fertilizers , organic nitrogen applied as fertilizers e.g. animal manure, nitrogen in crop residues. Many fertilizers contain nitrogen, part of which is released into the atmosphere as nitrous oxide.

The above inputs in the agricultural phase are often specific to the study of the individual farm. There can be different values between different farms due to the differing production conditions and methods. The uncertainty for this therefore must be considered when analysing results. Reasonable assumptions were made in respect to productions climates and the agricultural processes for each product.

Depending on the product, one or more of the above emission sources can be not applicable, therefore omitted from specific LCAs. Notably, land use change is not included in a number of papers referenced in this assessment. The effects of land use change are very product/country of origin specific and therefore it is hard to generalise. For example, the land use change of the majority of olive oil production in Greece would be negligible as olive trees have been established for a number of years and are often the only crop able to grow in the environment, whereas the effects of land use change are significant for beef produced in Brazil due to the large amount of deforestation required to produce grazing land.

2.8 Processing

Analysis of the environmental burden linked to processing takes into account the GHG emissions from the energy consumption to turn the raw product into the final item that is sold. Raw materials are subjected to processing operations before they arrive at Deya Brewing. The majority of this energy consumption is the electrical and gas use of capital machinery. Data was gathered from suppliers in regards to processing of malt and hops, which accounts for around 90%

of the total weight of solid ingredients. For all other processing information of raw materials, calculations were based on reports for similar products and the GHG statistics from the energy consumption of processing plants. Where processing would happen in the UK, the electricity and gas emission conversions have been adjusted from the country of origin to the UK values as seen in the Department for Business, Energy Industrial Strategy 2020 report.

The processing of turning the raw materials arriving at Deya to the final beer is multi-staged and generates different sources of GHG emissions. For every process figures were obtained via bills for monthly emissions and then scaled to form processing emissions for an average beer sold. To determine a breakdown of each process per functional unit, monthly figures were compared against total beer sold in the respective month.

- **Electricity and Gas**
  Although electricity & gas figures are gathered as a site total, the vast majority of electricity gas consumption used by Deya will be attributed to the brewing process and storage of products via refrigeration. For gas, Well-to-Tank (WTT) was added for upstream Scope 3 emissions associated with extraction, refining and transportation of the raw fuel sources prior to combustion. For electricity WTT were also taken into account as well as transmission and distribution (T&D) losses from associated grid losses.

- **Fermentation**
  As yeast metabolises sugars in fermentation vessels CO_2 is released as a by-product. The amount of CO_2 released will depend on the time of fermentation, the ingredients used and the alcoholic rating of the beer which all differ for each product. Data for the fermentation emissions were estimates using equations 1 and 2 below. Each product was analysed for the month of September to gather estimates of yearly figures attributed to fermentation.

  For beers under 6%:

  $$\frac{31 \cdot \frac{VolumeofBeer}{117} \cdot 0.34}{2.2046} \tag{1}$$

  For beers over 6%:

  $$\frac{31 \cdot \frac{VolumeofBeer}{117} \cdot 0.43}{2.2046} \tag{2}$$

- **Carbonation**
  After the fermentation process is complete carbon dioxide is re-introduced before the packaging stage to carbonate the final product. Even though sealed, the carbon dioxide will enter the atmosphere once product has been consumed. The brought carbon dioxide is a by-product of power generation therefore is assumed to have a GWP of zero for the production phase. The liquefaction, purification and delivery phase were all calculated to achieve GHG emission calculations.

- **Water Demand**
  By mass water makes up around 90% of the weight of the final product and is used in high volumes in the brewing process as well as being used for cooling and cleaning. Water supply and water treatment were considered separately in accordance to carbon emission factors. However, both water supply and water treatment were assumed to be equal as even if water is not treated on site, the water cycle will mean all water will eventually need treating.

- **Refrigerant** In cold storage refrigerant use is considered in Scope 1 emissions with rate of leakage estimated at 1% per annum [5]. The contribution of leakage to refrigerants carbon footprint is 90-95% through direct emissions to the atmosphere and subsequent need for more refrigerant to be produced [6]. Unlike all other processes, the emissions rate of refrigerant does not vary with beer production rate.

2.9 Packaging

The makeup of total packaging emissions was comprised of the ingredients coming into Deya's facilities, the initial packaging of beer product & final delivery packaging for distribution. The most significant aspect analysed was the packaging of beer which (by quantity) is majority aluminium cans. Other packaging means are 375ml glass bottles and Stainless steel kegs. For analysis it was assumed 20% of the sellable volume is kegged and the remaining canned, as none of the brews analysed were bottled. The distribution allocation for kegs and cans were 100% and 90% respectively with the remaining cans sold from the tap room.

2.10 Upstream Packaging

Deya Brewing ingredients masses were recorded to allow for respective packaging calculations. Four primary materials encompass the ingredients packaging: Cardboard, Kraft Paper, Polypropylene (PP) Polyethylene (PE). A mixture of these primary materials are also used, hence packaging analysis was adjusted accordingly. Worst case assumption of energy needed for primary production was recorded for each material. Although some suppliers may have recycled packaging, it was determined that not enough evidence is provided to allow for recycled material emission factors. To determine packaging sizing and weights, product distribution volumes were calculated. Product volumes were then compared against standardised packaging volumes to gather an accurate packaging fit.

Cans coming into Deya's facilities has one pallet and 3 ties per 5000 cans and is recollected by canning distributor. Canning packaging was therefore assumed to have zero emission burden associated with it. However the upstream packaging for can lids, 30L kegs, and 20L kegs were analysed. 20L & 30L kegs are packaged in groups of 27 & 40 respectively with wrapped LDPE film and a crate. Can lids were estimated to be packaged in groups of 20,000 with LDPE.

2.11 Product Packaging

The main source of Deya's product packaging is 500ml aluminium cans. Data on CO_2e emissions from aluminium cans includes average EU recycling rate of 72.9% [7] which was consistent with suppliers' information. Glass bottles and kegs are also used as packaging methods, although in substantially lower volumes. Glass bottles are non-returnable in the UK but widely recycled with the analysis based on a green glass recycling rate of 75% [8]. Kegs are reused consistently throughout the UK, promoting a circular system of packaging and therefore were not considered to have an emission burden associated with them and were instead considered under the capital goods section of this report.

2.12 Distribution packaging

Delivery packaging was calculated for online orders in quantities of 6, 12 and 24 cans of beer. Delivery items for all three delivery quantities analysed include a cardboard box and a liquid separator. Size and weight were calculated for complete packaging and emissions analysed in accordance to associated emission factors. Other packaging materials that were analysed for Scope 3 emissions include: can trays, tape rolls, pallet wrapping, edge guards and pallet strapping.

2.13 Waste

Worldwide, food waste by retailers and consumers is estimated to be 9% of total food emissions [9]. Put into context this is slightly higher than all of the emissions from aviation, proving that waste reduction is pivotal in the reduction of total food emissions. Product wastage was analysed as the difference between the volume of product that was signed off and the sellable product. Waste figures have been added into both standards via analysis of the sellable volume instead of the wort volume or sign of volume produced.
Deya Brewing has a "Zero to Landfill" policy which is intended to reduce the amount of primary production of material needed in the economy. End of Life (EOL) analysis was conducted for the all Deya's upstream packaging, with all items assumed to be recycled or reused.
Solid waste products are collected by local farmers to be used as feed. This promotes a circular approach to agricultural methods and will mean both Deya Brewing and the farm in question will share the burden of GHG emissions in the production of the associated grain. However, GHG emission saving from farming collection of wort has been omitted from this study as the saving is considered to be attributed to the farm using the solid waste.
Consumers were not questioned on usage but 100% of the product brought was assumed to be consumed due to the shelf life of beer. It is however assumed that the disposal of wort has no emissions due the further use as feed.

2.14 Brewing Capital Equipment

Capital goods were recognised in this study as machinery used in the operations of the brewing processes for Deya Brewing being brought since operations were scaled this year. Calculations were based on bill of materials and their respective processing and transportation emission factors. Therefore, exclusions from the capital goods analysis were cold room exterior, warehouse building & office space. A list of the capital goods analysed, is shown in Table 4. Where exact figures were unable to be collected, estimates were made of material type and weight. For non-uniform capital goods electric components were separately analysed and given a percentage of the total weight.

3 Grouped Results

The results are separated into Grouped results, GHG Protocol Corporate Standard results and GHG Protocol Product Standard results. For reference about representing of results in product and corporate standards, see Table 1 & Table 2 in the methodology section of this report.
The following section outlines GHG emissions for: agricultural inputs, transport, processing, capital goods, waste packaging. Each section of results has been weighted to best display the relative emission burden. For a full breakdown of results please see supplementary data. Transport of agricultural products were deemed part of "agricultural input" results and has been omitted from the transport section.

Table 4: The breakdown of the product specifications of capital goods at Deya Brewing, (SSL: Stainless Steel).

Capital Good	No. of Items	Main Materials	Total Weight (Kg)	*Capital Good*	No. of Items	Main Materials	Total Weight (Kg)
Brewkit	1	SSL	5800	Brewing Tanks (80HL)	10	SSL, Ri Foam Insulation	18500
Canning Line	1	SSL Electricals	1000	Canning Line	1	SSL	750
Canning Line Labeller	1	SSL	40	DePal	1	SSL	1500
Refrigeration System	2	SS304, Control Unit	112	Steam Boiler	1	SSL 304	4650
Grain Silo	1	Galv Steel	1806	Forklift	1	EV mini Ref.	4477
Water Tanks	1	MDPE	210	Water Filterer	1	SSL, HDPE	550
Kegs (30L)	100	SSL	1000	Kegs 20L	100	SSL	750
CO_2 Canisters	16	SSL	65	CO_2 Tank	1	SSL	520

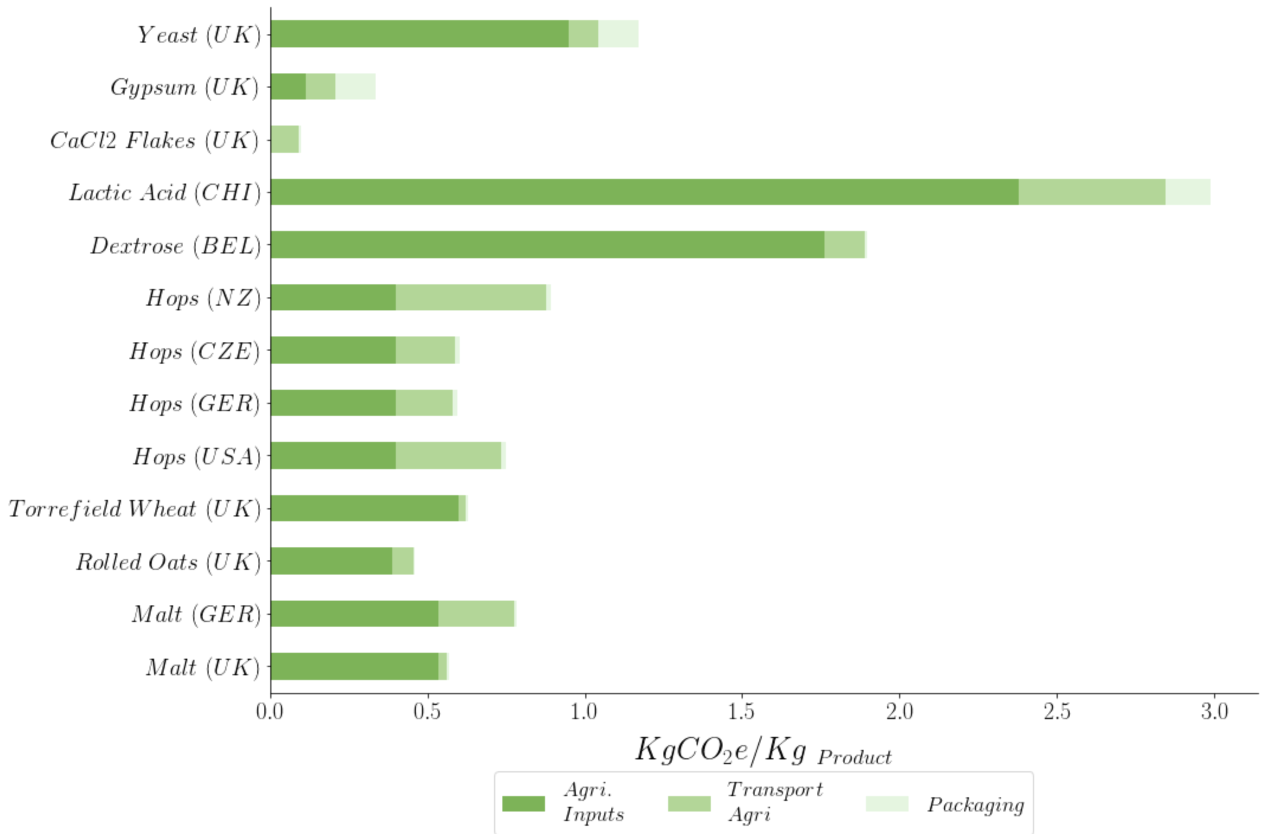

Figure 2: The emissions related to agricultural products at Deya

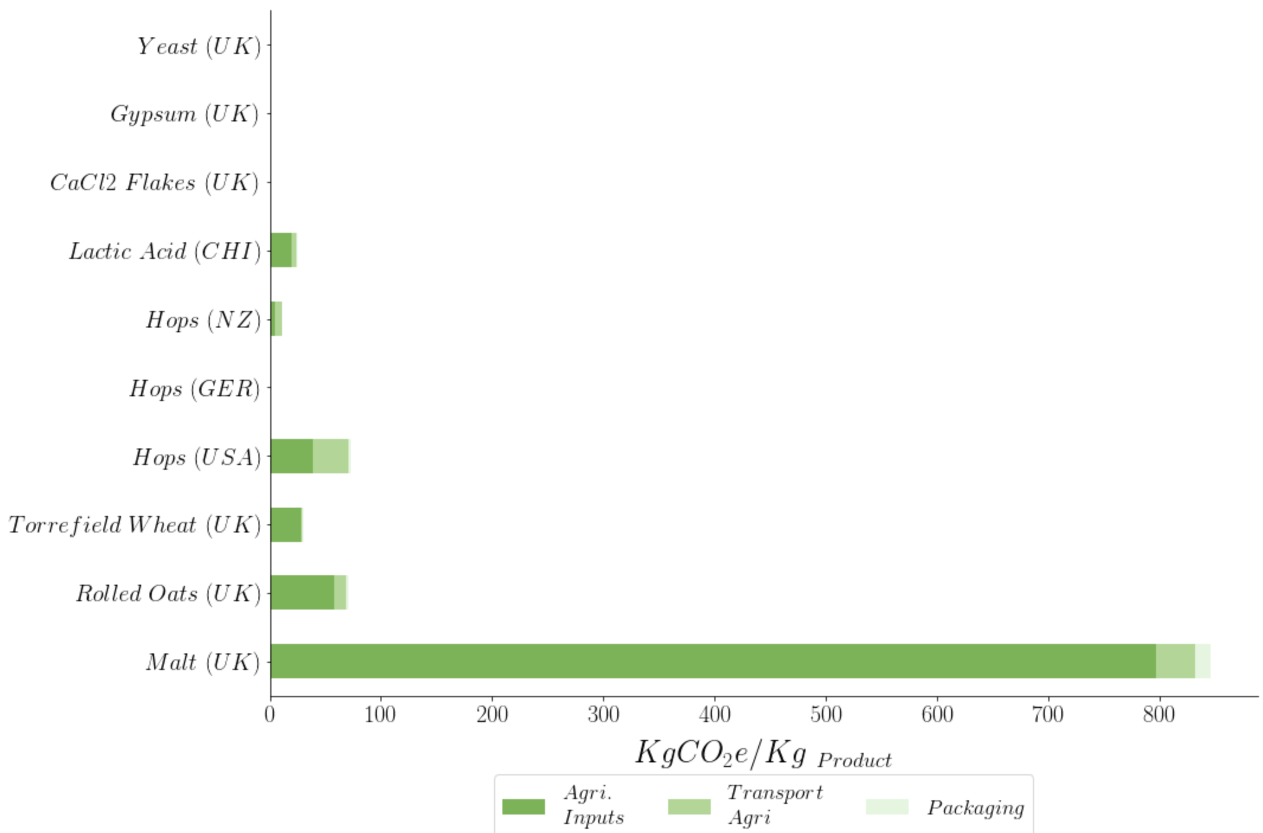

Figure 3: Agricultural emissions weighted for their usage in SRM

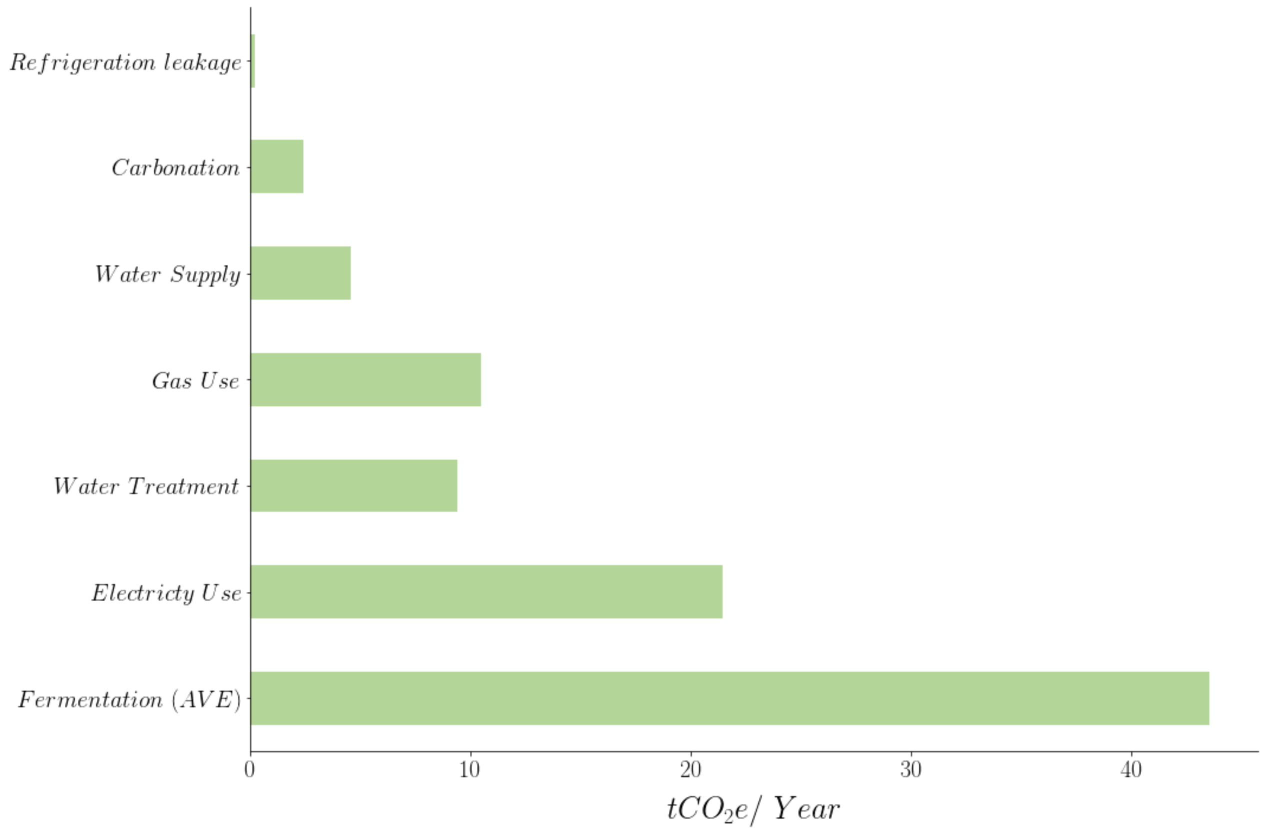

Figure 4: Emissions from Processing at Deya, with packaging including production & EOL emissions.

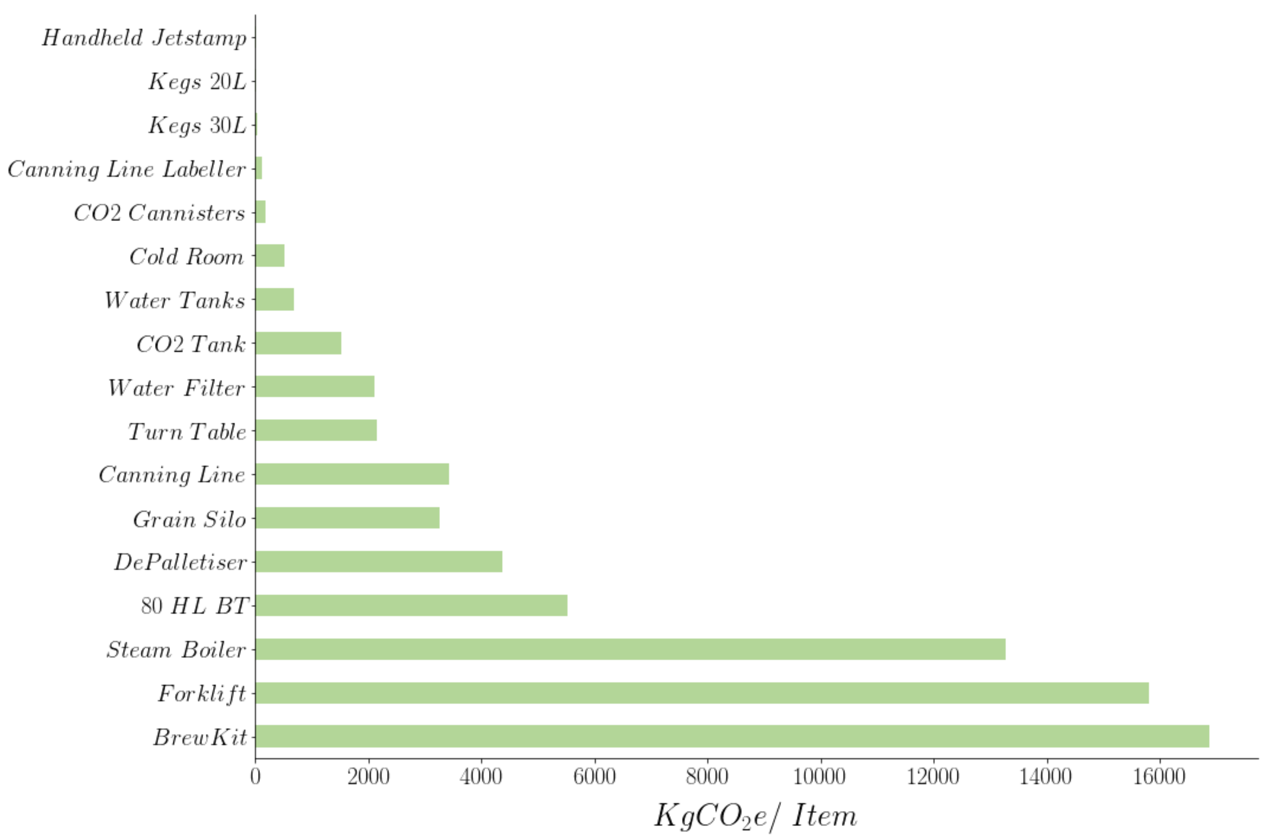

Figure 5: The emissions related to production/ purchase of capital goods.

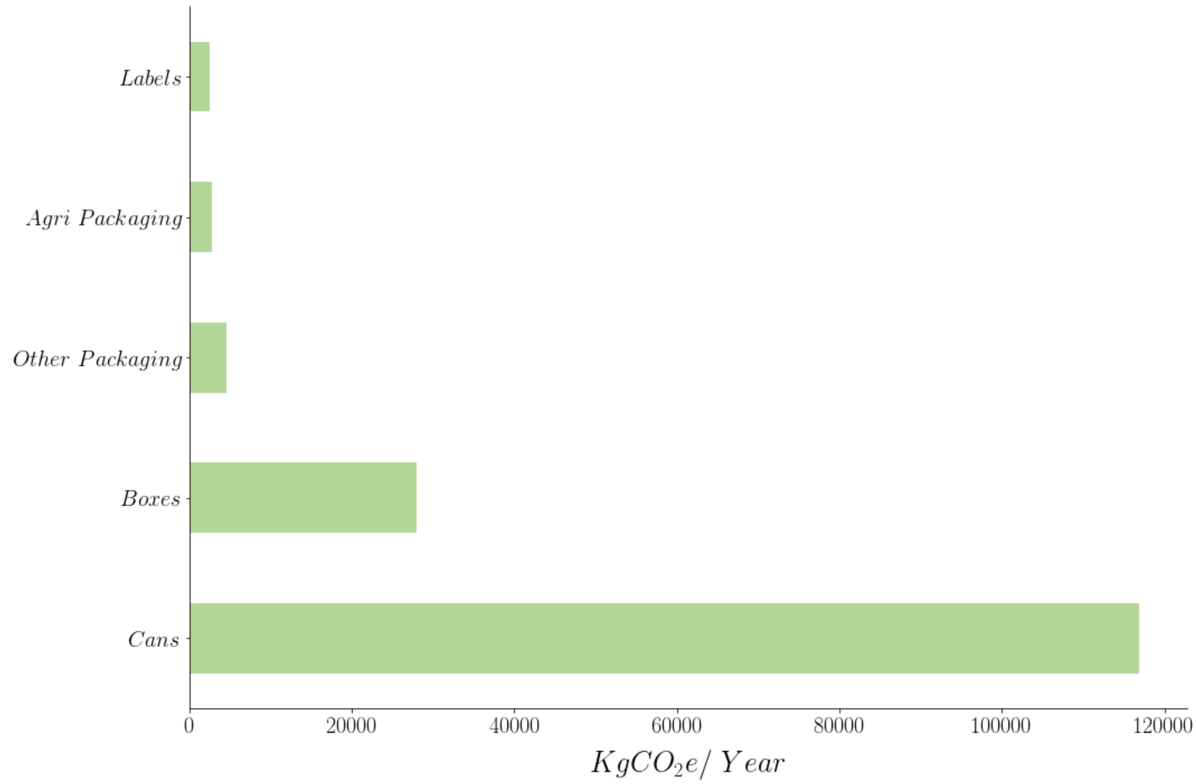

Figure 6: The yearly emissions due to packaging at Deya

3.1 Agricultural Products

In Figure 2 all products show relatively higher emissions coming from the agricultural inputs apart from calcium chloride which is collected as a by-product in the Solvay process for the production of sodium carbonate and gypsum which has a relatively low production emission factor compared to its PP tub packaging.
Transportation of agricultural products ranges from 0.024 $KgCO_2e$/Kgproduct (UK) to 0.477 $KgCO_2e$/Kgproduct (NZ). Consequently, local sourcing of products lowers the embodied emissions from transportation however, HGV travel to a port will increase the GHG emissions significantly. Thus there is no linear correlation between country of origin distance from the UK and transport emissions.
The packaging results for the agricultural products consists of both production and EOL phases. Although proportionally GHG emission from packaging are small, bulk packaging is shown to reduce emissions per kg of product compared to products which are packaged in smaller quantities. The highest relative packaging emissions is seen with yeast and gypsum, packaged in PP tubs per 5kg (0.14$kgCO_2e$/kg), whereas the lowest is seen with wheat and oats packaged in Kraft paper per 25kg (0.009$kgCO_2e$/kg).

3.2 Processes

The results in Figure 3 have been presented with respect to per 500ml of beer sold. The highest contributor is fermentation, where an average was taken of the three products analysed. Beer wasted has been included by all processing factors being related to sellable volume rather than sign off volume. Averaged, the beer wastage is 6.9%. Reduction to this waste percentage figure would lead to a reduction in processing by the same percentage as less volume of beer would have to be processed to achieve the same sellable volume.

3.3 Transport

Due to the different ways of purchasing products from Deya Brewing, transport can be compared via average customer pick up emissions and product delivery services. Buying product via pickup was calculated to have 2.84 times the emissions of delivery methods due to the small quantity brought per customer trip.

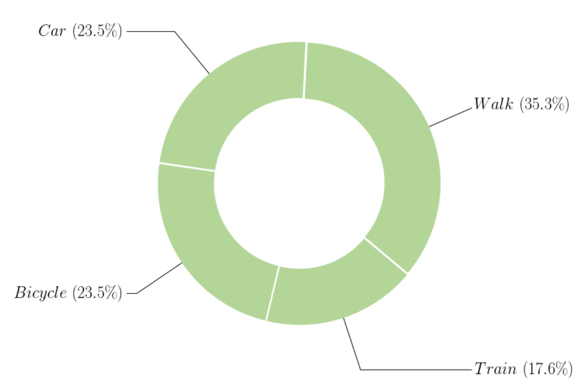

Figure 7: A breakdown of the different types of commute by employees

Emissions from employee commutes show much lower levels of car use compared to national averages. A 2015 study shows comparable "Urban with significant Rural" office locations to have 11% commuting by foot, 3% by bicycle, 4% rail and 77% automobile [10] . Seen in Figure 6, Deya Brewing's split shows walking to be the main form of commuting (35%), with no emissions associated. Vehicle commuting is responsible for 23% of all commuting but 59.5% of emissions.

3.4 Capital Goods

Seen in Figure 4,the total GWP for capital groups is 127.4 tCO_2e for the 2020 year. A significant proportion of the total burden is made up of the goods directly relating to brewing operations, due to the large mass requirements for the brewing of products. Other significant capital goods outside the brewing process include the forklift used for warehouse operations and the canning equipment used for packaging.

3.5 Waste and Packaging

Figure 5 demonstrates the total GHG emissions (production & EOL) for all packaging types over the year. The canning process is seen to have a significant proportion of the overall packaging emissions due to the volume of beers canned compared to other packaging means. However, packaging in aluminium cans is less emission intensive than alternatives. Glass bottles are seen to have 1.95 times higher emissions through the lifecyle of the product. Cardboard boxes are also a significant contributor due the magnitude of use but are necessary for delivery. In Figure 5 "Other packaging" includes: edge guards, pallet strapping, pallet wrap, tape rolls, the packaging of delivered kegs & cans & canning trays.

4 Corporate Standard

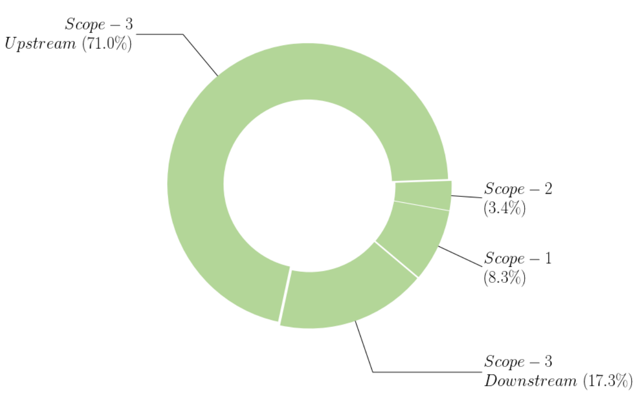

Figure 8: The percentage breakdown of all emissions at Deya for all scopes, totalling 639 tCO_2e.

The relative scope emissions shown in Figure 7, shows that 8.29% of the total emission burden for the year is associated with Scope 1, 3.35% with Scope 2 and 88.36% with Scope 3. All specific scope emission breakdowns are shown in the following sections where fermentation, electricity usage and agricultural inputs are all the highest relative emission contributors.

4.1 Scope 1

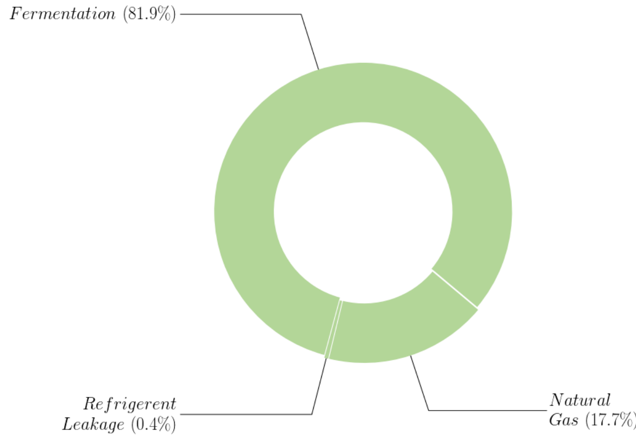

Figure 9: A breakdown of emissions related to Scope 1 activities at Deya

4.2 Scope 2

In relation to Deya Brewing the only contributor to Scope 2 emissions is the generation of purchased electricity. This totalled is 21.42 tCO_2e/year.

For electricity, Well-To-Tank emissions and transmission and distribution losses were also considered by implemented into Scope 3 emission contribution. Scope 2 GHG emissions represent only 3% of total emissions in the corporate standard at Deya Brewing.

4.3 Scope 3

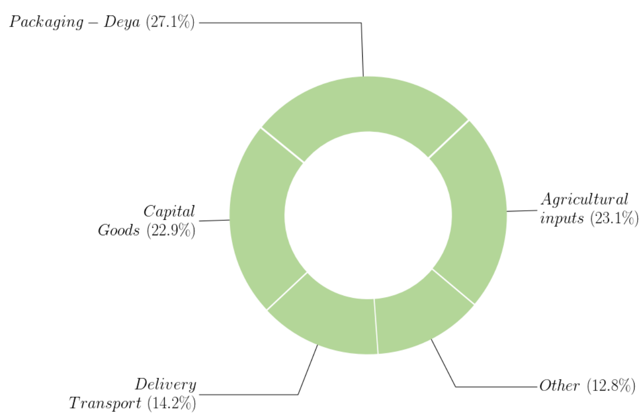

Figure 10: The Scope 3 related emissions at Deya Brewing. Other includes emissions related to carbonation, waste, employee/ customer travel, transport emissions and water burden and treatment.

5 Product Standard

As seen in Figure 10, all beers have very similar GWPs. Differences in values mainly arise from both Agricultural Inputs due to the sometimes long travel distance accompanied with certain ingredients, and fermentation.

As fermentation is a function of ABV strength, ITH therefore releases more GHG's into the atmosphere in the brewing process.
The data has also been tabulated and can be accessed in the supplementary data section of the report. Like-for-like products, with equal calculated CO_2e, are represented as a group within the main body text, however all product names and CO_2es are given within the supplementary data.

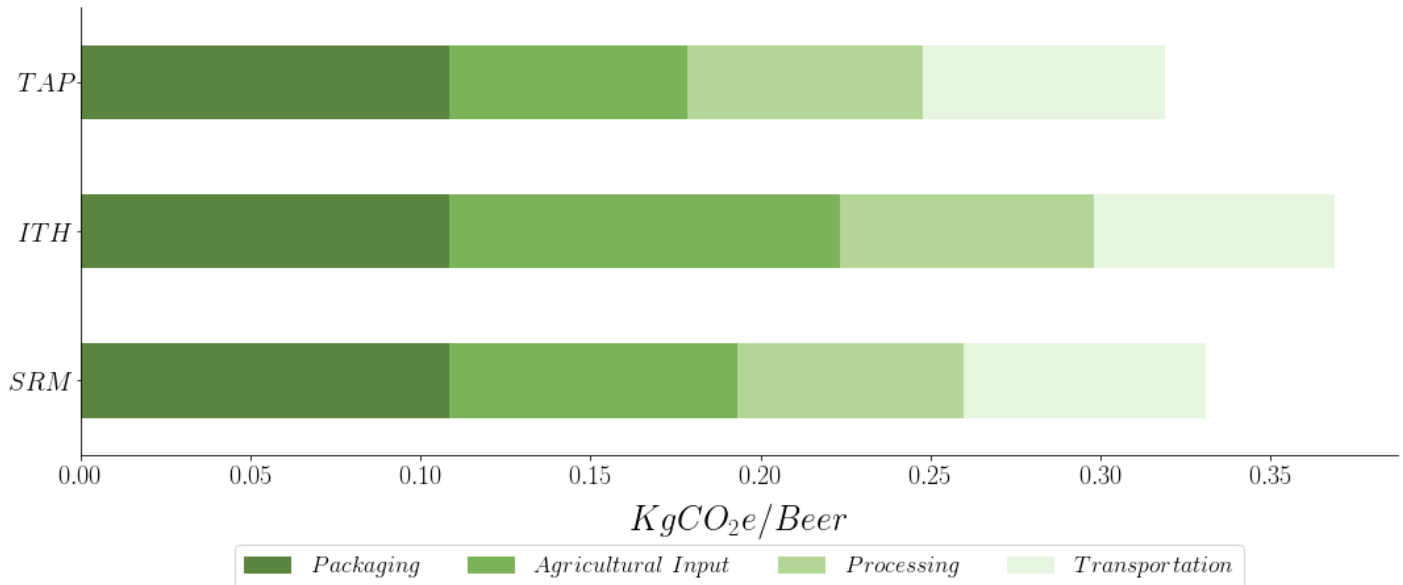

Figure 11: A breakdown of the emissions in producing one can of beer for *Deya's* 3 most popular beers.

5.1 Sensitivity Analysis

Parameter choices used when modelling include a certain degree of uncertainty. To analyse the effect of different uncertainties, a sensitivity analysis was conducted for various aspects. For each sensitivity analysis the effect was recorded on each Product Standard and the total GHG emissions for the year.

• Agricultural transportation: the effect of changing maximum van transportation from 150km to 250km was conducted.
• Customer pick up: The effect of changing average purchased products from 10 to 5 was analysed.
• Agricultural Processing: Malt Ingredients processing was alternated by +25%.
• Refrigeration Leakage: Refrigeration leakage was increased from 1% to 5% .

Table 5: Sensitivity analysis results, showing percentage change in products and yearly emissions

Factor	SRM (%)	ITH (%)	TAP (%)	Yearly Emissions (%)
Van transportation	0.23	0.43	1.34	0.29
Customer Purchases	4.80	4.30	4.98	2.99
Refrigerant leakage	0.40	0.35	0.41	0.14
Malt processing	2.04	2.51	2.91	2.37

The results of the sensitivity analysis are shown in Table 5. Van transportation limit change had negligible effect on both the GHG emissions for each product and total yearly emissions. TAP shows the most significant change due to sourcing of malt being from outside of the UK.

Refrigerant leakage rates shows negligible and comparable effects on all three products analysed. The amount of refrigerant used in cold rooms is small compared to industrial scale application and therefore emission rates are low.

The alteration of malt processing by 25% has had a low to moderate with total emissions for the year changing by 2.37%. This is due to the burden of agricultural input emissions from malt being relatively high. 25% change is seen as an extreme case variance.

The greatest change in yearly emissions was created by simulation of tap room collection to half from 10 beers to 5. This shows a weighting of around 4% change for the emissions relating to all three products analysed. Again, this was seen as an extreme case variance.

6 Discussion

Analysis of Deya Brewing has highlighted the main carbon hotspots to be agricultural emissions, inhouse packaging, capital goods and delivery transport. None of these significant hotspots are related to Deya's direct practices (Scope 1 & 2) but are made up of varies indirect emissions coming from other sources. Although packaging is a major contributor to Deya's total emissions, current literature shows that 500ml cans as well as kegs to be less of an environmental burden compared to glass or smaller cans. Furthermore, 500ml cans have high packaging efficiency to allow for tighter volume in packaging, subsequently reducing the required space uptake, reducing the GHG emissions from delivery. Deya Brewing's Zero to Waste policy allows the contribution of end of life material waste to only be 0.25% of total GHG emissions. This should be continued to promote circular economy practices.

Although good practices have been shown in packaging, local sourcing, employee journeys and waste management, Deya Brewing, like all companies, has the opportunity to further reduce its GHG emissions. The following section outlines possible mitigation techniques for all scopes to reduce emissions further before offsetting practices are conducted.

6.1 Scope 1 Reductions

Decreasing Scope 1 emissions is vital in prevention of global warming. If every company were diligent in reducing their own direct emissions, indirect emissions will subsequently reduce throughout the world. Fermentation, which relates to 82.1% of Scope 1 emissions, is infeasible to reduce while brewing beer at a standard to high ABV. However, If the CO_2 created was captured, stored and re-introduced into the beer in the carbonation phase of the process this would therefore save emissions relating to the purchased CO_2 (2.4tCO_2e/year).

Natural gas, used for the heating process, has possible carbon reduction pathways. Electrification is the cleanest way to reduce emissions from natural gas. As the UK national grid carries on its decarbonisation trend, the emissions from electricity will subsequently decrease, meaning this will continue to be cleaner, reducing emissions further in the years to come. Alternatively, biogas certificates can be purchased for the supply of natural gas used. Biogas is created from the agricultural or food waste in an anaerobic digester, where methane is extracted and supplied to the gas grid.

Refrigerants are incredibly potent GHG's and contribute significantly to global warming around the globe with the release of hydrofluorocarbon (HFCs) contributing to 1.05GtCO_2e [11]. Although R449A has around a third lower GWP than common alternatives (R404A) by being a HFO-HFC blend there are still other refrigerants that have significantly lower GWP used in commercial and industrial settings. Natural refrigerants such as propane, ammonia, propene or carbon dioxide all have GWP's of 3 or below and can therefore almost negate all associated GHG emissions from leakage (0.22CO_2e/year). Furthermore, pure HFOs like R1233zd (GWP=5) or R1234ze (GWP=7) both have the potential to be used to reduce emissions (0.22t_2).

6.2 Scope 2 Reduction

Electricity demand is the sole Scope 2 emission for Deya Brewing. The brewing process intrinsically has high electricity demand due to the large scale, time consuming nature of the processes. Currently best practices for electricity include purchasing power agreements from renewable sources to ensure investment into renewable infrastructure. Supplementing grid electricity demand can also be achieved with photovoltaic (PV) arrays to allow for conversion of solar energy into electricity to be reduce grid demand.

6.3 Scope 3 Reduction

Due to Scope 3 emissions being indirect, for some aspects it is difficult or infeasible to reduce emissions. For example, capital goods are necessary in the brewing process. Although creating high initial GHG emissions from purchase, they can return net loss of emissions over their lifetime by creating more efficient processes in brewing, storing or delivery. It is therefore important to buy items that last to ensure replacement goods are minimised.

- **Ingredient Reduction**
  Agricultural inputs represent 129.0tCO_2e of Deya's emissions. The largest individual item by weight and emissions is malt. By sourcing completely organic malt, a recent study shows a possible reduction of 0.09kgCO_2/kg malt. Estimated over the year this could decrease emissions by 16.1 tCO_2e/year at current production rates.

  The location of origin of ingredients used in high volumes impact the total agricultural carbon footprint. If malt is gathered solely from UK compared to Germany this will have an estimated saving of 143kgCO_2e per batch. The higher the mass used of products the more significant savings can be seen by sourcing from local origins.

- **Waste Reduction / Water**
  For September 2020 7% of Deya's output was wasted. Waste reduction methods for breweries continue to develop as companies try to increase efficiency, thus reducing emissions. Although some waste is inevitable within the brewing processes, best practices can be implemented to reduce beer wastage. There is equipment such as separators and decanters to create drier by-products by recovering beer.

  Water is used in high volumes for the brewing process. Although water use and treatment only contributes to 2.2% of total emissions water demand should be minimised due to possible future restrictions. As droughts continue to become more frequent as climate change causes temperatures to rise, water will become scarce. If companies can mitigate total water consumption in the short term, this will lead to reduction in pressures on future use. Water management strategies are reviewed at length in the Brewers Association paper on this subject and best practices can be implemented to reduce Deya Brewing's water demand

- **Transport**
  Although Delivery of Beer is the largest main contributor to yearly CO_2e emissions for transport, due to the lack of viable 'green' alternatives there are limited options for reduction. Reductions in Transport should can aimed at customers driving to the tap room. Any methods to incentives other methods of transport rather than driving, or increasing the average order size would be the best way to reduce emissions related to transport.

7 Conclusion

An environmental assessment was undertaken for the GHG emissions at Deya Brewing in line with the GHG Protocol corporate and product standards. Scope 1, Scope 2 & Scope 3 emissions were all analysed and emissions for three individual beers, packaged in 500ml cans were subsequently calculated. Across the three scopes 8.36% of the total emission burden for the year is associated with Scope 1, 3.38% with Scope 2 and 88.26% for Scope 3. Scope 3 emissions are split into upstream and downstream activities of which 81.59% of Scope 3 emissions relate to upstream and 18.41% to downstream.
For the three products analysed: ITH, TAP SRM the Global Warming Potential (GWP) was equal to 0.38 $kgCO_2e$, 0.33 $kgCO_2e$ and 0.34 $kgCO_2e$ respectively per 500ml can sold. If GWP's are implemented on labelling for cans sold then customer will be able to be educated in the emission burden of their purchases. This number can be easily compared against others with little background knowledge, thus allowing consumers to differentiate between products.
If Deya Brewing beer products are to be considered carbon neutral, it is recommended that all Scopes are offset for the year 2020, equating to $639tCO_2e$. For Scope 1 & 2 offset plans, Deya Brewing will have to offset $75tCO_2e$.

8 Supplementary Data

To be made available on request

9 Assurance

Tyndall Sustainability has undertaken a first party limited assurance review of the 2020 Greenhouse Gas Analysis of Deya Brewing, with the conducting participants not responsible for the GHG inventory process. Conflict of interest was avoided by best academic integrity practices and a mutually exclusive reviewed data by participants with necessary academic GHG inventory competencies.
Procedures of assurance were performed by counter calculation and were dictated by inspection of documents, assessment of the appropriateness of methods and cross-referenced verification of obtained data.
Based on the review performed and the data gathered, nothing has come to our attention that the inventory process and subsequent GHG emission finding are not in accordance with the GHG Protocol Corporate and Product Standards.

Bedford, 23/11/2020

Tyndall Sustainability

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