InchDairnie Distillery Carbon Footprint

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Report for InchDairnie Distillery

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Executive Summary

This report provides a carbon footprint for InchDairnie distillery for the calendar year 2019. The assessment has been undertaken to provide a baseline for future comparisons, identify target areas for emission reductions, and provide a transparent method to encourage industry consensus around a common carbon reporting process.

The results have been calculated following the guidance of the Greenhouse Gas Protocol Product Life Cycle Accounting and Reporting Standard. The boundary of the footprint includes:

- Production of whisky ingredients (malt, yeast, and water);
- Upstream transport to bring ingredients to site;
- The purchase and delivery of casks for maturing the whisky;
- Electricity and natural gas consumed during the distilling process;
- Downstream transportation of pot ale and draff; and
- Disposal of waste water.

This boundary represents the stages of production currently undertaken by InchDairnie, and this is not therefore a full cradle-to-grave assessment. This boundary will be extended in future alongside further development of InchDairnie's operations.

The total greenhouse gas emissions and greenhouse gas emissions per litre of alcohol (expressed as CO_2 equivalents), are shown in Table 1. The full method used to derive these results (in addition to results that include biogenic carbon) is presented in the main report.

Table 1: Summary of Results

Total Organisation Footprint	**4,504 Tonnes CO_2e**
Per Litre Alcohol	**2.4 Kg CO_2e**

The results in Table 1 are based on using electricity from the mains grid. During 2020 the distillery changed its electricity supply contract to exclusively wind power supplied by Orsted. This report therefore also includes a scenario where electricity is generated by renewable sources. In this scenario, the total footprint becomes 4,280 Tonnes CO_2e, and the per litre alcohol footprint becomes 2.3 Kg CO_2e.

InchDairnie sends waste draff and pot ale to a local anaerobic digester which produces biogas. The biogas is supplied into the gas network where the distillery takes its own gas supply. This report also includes a scenario to calculate the potential impact on InchDairnie's annual carbon footprint if it is assumed this biogas replaced 100% of the distillery's natural gas consumption. In this scenario, 1,407 Tonnes CO_2e a year would be avoided. Assuming that both renewable electricity and biogas were consumed by the distillery, the total annual footprint would be 2,873 Tonnes CO_2e and 1.53 Kg CO_2e per litre alcohol. These changes are both anticipated to be in place in 2021, and therefore 2,873 Tonnes CO_2e is expected to be close to the future annual GHG emissions generated by the distillery within the present footprint boundary.

Glossary and Abbreviations

Term	Definition
Biogenic Carbon	Carbon associated with the natural carbon cycle, sequestered or released by biological materials.
CO_2	Carbon dioxide.
CO_2e	Carbon dioxide equivalents. A measure used to compare warming levels between CO_2 and other greenhouse gases.
Carbon footprint	A carbon footprint is the total amount of greenhouse gas (GHG) emissions emitted by an organisation, event or product. For simplicity of reporting, it is often expressed in terms of CO_2e.
Emissions factors	An emissions factor tells you the CO_2e emissions per unit of activity.
GHG	Greenhouse Gas. Used to refer to the group of gases that contribute to global warming.
Market based and location based	The 'location-based' system of carbon reporting uses the grid average electricity emissions factor. The 'market-based' system of carbon reporting uses the carbon intensity of an organisations' specific electricity tariff. When purchasing a green electricity tariff, electricity emissions can be considered to be zero in the market-based reporting method.
WTT	Well-to-tank emissions. This refers to GHG emissions associated with the upstream extraction, refining and transportation of raw fuels.

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1.0 Introduction

InchDairnie Distillery is a modern whisky distillery which has been in production since 2015. Its single malt product is expected to mature on-site in seasoned casks for at least 10 years before being ready for the market. A percentage of production is currently sold and transported to another whisky blender. Packaging and bottling for the single malt has not yet been introduced into InchDairnie's manufacturing process, however design and development for this is due to begin shortly.

This report presents a carbon footprint for whisky production at InchDairnie's distillery. The footprint has been prepared using recommended methods in the Greenhouse Gas Protocol Product Life Cycle Accounting and Reporting Standard.[1] The steps undertaken to prepare this footprint and the associated results are set out in the following chapters:

1) **Goal and Scope Definition:** This chapter details the production stages and processes included within the assessment.
2) **Lifecycle Inventory (LCI) Analysis:** This chapter sets out the activity data sources used to undertake the footprint and provides the greenhouse gas (GHG) emissions factors applied in carbon dioxide equivalent (CO_2e) values.
3) **Lifecycle Impact Assessment (LCIA):** Within this chapter activity data and GHG emissions factors are converted into the carbon footprint (presented in CO_2e) associated with InchDairnie's operations.
4) **Results Interpretation:** This chapter draws out key findings from the impact assessment and comments on opportunities for refining the method and reducing emissions.

This report has been prepared to provide transparency regarding the method undertaken to deliver the footprint and the associated results. Whilst this will aid comparisons with other products and whisky producers, readers are advised not to make comparisons based purely on the data within this report. The differences in methods between footprint assessments, and the varying nature of production systems, mean taken in isolation comparison of results is not recommended. Accurate comparisons are best achieved through individual studies, or applying a standardised assessment method that is followed industry wide.

[1] Greenhouse Gas Protocol Product Life Cycle Accounting and Reporting Standard https://ghgprotocol.org/product-standard

2.0 Goal and Scope Definition

2.1 Goal

Environmental sustainability is a key value that InchDairnie has committed to prioritise throughout its operations. The company has produced an Environmental Policy and a Sustainability Report, and has already undertaken three reviews through Resource Efficient Scotland including: a Food & Drink Waste Opportunity Review; Energy Resource Review, and a Solar PV Feasibility Study.

InchDairnie intends to take a holistic view of all its production activities to progress its goal of becoming a Carbon Neutral business. This carbon footprint report has been produced to provide a baseline assessment of the company's carbon emissions. This will be used to identify priority areas for low carbon interventions and track ongoing progress.

In addition, InchDairnie hopes this footprint review will prompt a broader discussion within the industry regarding:

1) Common practice for whisky production carbon footprinting methods, and expectations regarding methodological transparency, to enable comparability between products and organisations; and
2) Ways and means of reducing emissions to encourage industry wide action to combat climate change.

2.2 Scope

The central features of the scope of this assessment are presented in Table 2, and further detail regarding the system boundary is provided in section 2.2.1.

Table 2: Scope of Footprint

Scope feature	Description
Time period	Calendar year 2019
Location	InchDairnie's distillery is located in Glenrothes, Scotland, and all process inputs are sourced from the UK, with the exception of casks.
Greenhouse gases included	Where emission factors have been sourced from the UK Government's Greenhouse Gas (GHG) Conversion Factors, CO_2, CH_4, and N_2O are included. Within the third-party literature sources used the authors were not specific regarding the included gases, however present their results as CO_2e, suggesting inclusion of multiple gases.

Scope feature	Description
Functional Unit	The footprint has been calculated for calendar year 2019, over which period 1,882,398 litres of alcohol were produced. This enables the footprint results to be presented in aggregate, and on a per litre alcohol basis. **The functional unit for this study is therefore 1 litre alcohol produced by InchDairnie in 2019**, and this is derived by dividing the total GHG emissions generated throughout calendar year 2019 by the total litres alcohol produced during this period. Litres alcohol is used in this study as it is a standard unit used across the industry. A litre of alcohol is the bulk volume corrected to 20 degrees Celsius multiplied by the alcohol strength.

This assessment presents InchDairnie's footprint under two scenarios for electricity consumption: 1) using a location-based, 'grid-average' electricity emissions factor (i.e. the UK grid average electricity emissions intensity) and a market-based 'renewable' electricity factor, which takes into account InchDairnie's green electricity tariff (i.e. no GHG emissions are associated with electricity production). This green electricity tariff has recently been procured by InchDairnie, and therefore is not strictly within scope of the time period of this assessment. Therefore, the results presented in the market-based scenario should be considered illustrative of what InchDairnie's footprint would have been in 2019 had this tariff been in operation over this period.

Scope 3 GHG emissions from electricity consumption, gas consumption, and freight are included within this assessment. These scope 3 sources include the well-to-tank (WTT) emissions (upstream emissions associated with the extraction, refining and transportation of raw fuels) associated with electricity, gas and freight, as well as transmission and distribution losses for purchased electricity. These scope 3 emissions are separately presented in the relevant sections within the impact assessment chapter of this report. Under the market-based scenario, electricity scope 2 and scope 3 emissions are considered to be zero.

Also included within this assessment is a further scenario that looks at the potential impact of InchDairnie consuming biogas, rather than natural gas that is currently delivered by the mains gas system. It may be possible in the future for InchDairnie to be directly connected to a nearby anaerobic digestion facility. This is also the facility where InchDairnie's pot ale and draff is sent for conversion to biogas, and therefore presents the opportunity for a more circular distilling process. InchDairnie has requested an assessment of the impact of consuming biogas from this local anaerobic digester to inform its business planning. This impact is presented in section 4.3.

2.2.1 System Boundary

The attributional processes within the boundary of this assessment were established collaboratively with InchDairnie. The process stages included within the assessment are:

- **Material acquisition and pre-processing; and**
- **Production**

InchDairnie is yet to take its single malt products to market – these are presently being matured in storage. Therefore, this assessment does not follow a conventional cradle-to-gate or cradle-to-grave boundary. In accordance with the company's prioritisation of sustainability, this footprint is intended to be the first of several assessments that gradually extend in scope as InchDairnie expands its operations to include packaging and downstream transportation to suppliers, and future assessments will also include consideration of the end of life impacts of packaging. In due course the standard expectations for cradle-to-gate and cradle-to-grave assessments will be fulfilled. At present, a truncated system boundary has been selected to provide InchDairnie with useful insight into the present elements of its operations. A process map which sets out the full life cycle system boundary for whisky production, and the sub-set of processes included within this assessment, is shown in Figure 1. The flow of these processes is as follows and summarised in Table 3:

Material Acquisition and Pre-Processing

- Malt, yeast and water are the raw ingredients used for whisky production at InchDairnie.
    - Malt is produced through a 'malting' process, whereby barley grain is encouraged to begin germinating, and then stalled using a drying process. Within the process map in Figure 1 there are two processes relevant to malt. The first is 'Barley Cultivation'. This process purely represents the carbon sequestered by barley as it grows. This is known as biogenic carbon (see section 2.2.2 for further detail). The second process is labelled 'Malt Production'. This includes GHG emissions associated with growing and harvesting the barley (e.g. fuel and fertilizer), and electricity and gas consumption during the malting process.
- Casks are purchased for the maturing of whisky. The casks used are specifically selected to add to the flavour profile of the whisky.
- Malt, yeast, water and casks are transported to the distillery. GHG emissions arising from fuel used for this transportation are presented in the 'Upstream Transportation' process.
- Packaging materials are purchased to bottle and safely transport the whisky to retailers. Packaging is beyond the scope of this analysis as the materials are yet to be selected by InchDairnie.

Production

- Gas and electricity are consumed at the InchDairnie distillery site. Electricity is used for facility lighting, conveyor belts, pumps, and other equipment, and gas is used to provide heating during the distilling process.

- During distilling, the fermentation process releases CO_2. This is classified as a biogenic carbon source (see section 2.2.2 for further detail), and labelled with the small letter 'B' in the process map.
- The distilling process produces waste water, pot-ale (a syrup-like liquid) and draff (spent grain).
- Waste water is removed through the mains water system for processing.
- Pot-ale and draff are both transported off-site for processing at a local anaerobic digester.
- Once distilled, the whisky is placed within casks at the on-site warehouse for maturing. This process takes approximately 10 years, and during this time GHG emissions will accumulate through the use of electricity to light the warehouse. This stage of production is not included within the present study.
- Once mature, the whisky will be bottled. This production stage is not included within the scope of this assessment.

Storage and distribution – out of scope

- Bottled whisky will be transported to retailers.

Use – out of scope

- It is not anticipated any GHG emissions will be associated with the consumption of whisky.

End of life – out of scope

- The disposal and processing of packaging will be associated with GHG impacts at end of life.

Table 3: Processes within each Life-Cycle Stage

Life-Cycle Stage	Processes Included
Material acquisition and pre-processing	• Ingredient production (malt, water, yeast); • Cask production; • Cask delivery, yeast delivery, malt delivery (direct and WTT GHG emissions); and • Carbon sequestration within barley.
Production	• Electricity and gas consumption in the distillery (direct, WTT and transmissions and distribution emissions); • CO_2 produced through fermentation; • Waste water treatment; and • Transport of draff and pot ale.

2.2.2 Biogenic Carbon

Biogenic carbon refers to carbon associated with the natural carbon cycle, i.e. the absorption of carbon by plants through photosynthesis, and the release of this carbon back into the environment through various means (e.g. the burning of biomass, or the decomposition of biological materials). Within the scope of this assessment, biogenic carbon is relevant in two ways:

- Carbon taken up by barley as it grows; and
- Carbon dioxide released through fermentation within the distilling process.

Biogenic carbon is included within this assessment in accordance with the GHG Product Life Cycle Accounting and Reporting Standard. However, it is important to note that biogenic carbon is not considered to have a material impact on the net emissions of a product over its lifespan, as all sequestered carbon would be released during the full life cycle of the product. The presentation of biogenic carbon within the impact assessment should therefore only be used as a point of interest, and not to indicate any net sequestration impact of producing whisky. This is why the carbon footprint has been presented with, and without biogenic carbon. The scenario without biogenic carbon is most relevant to InchDairnie.

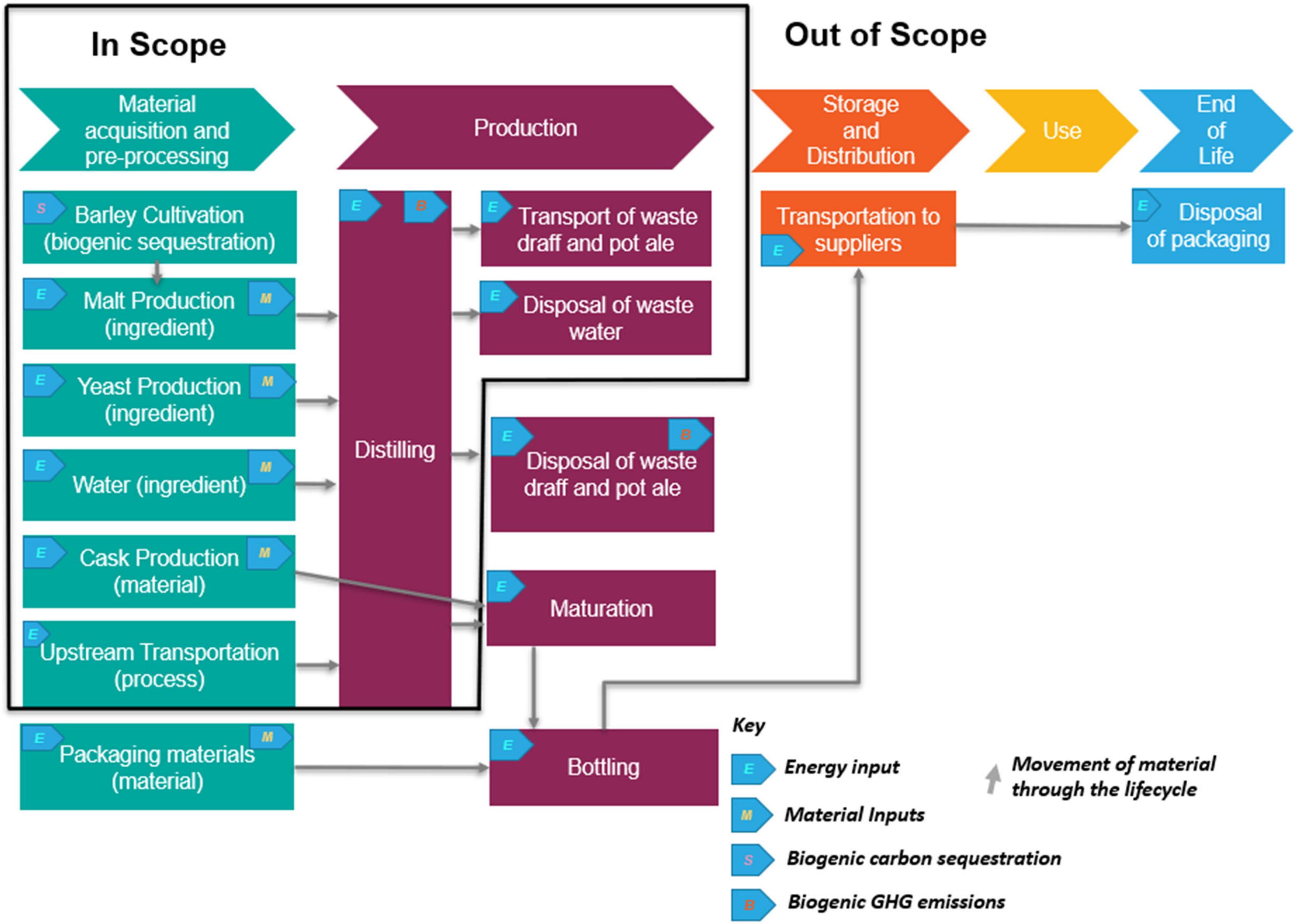
2.2.3 Land Use Change

Barley is a principal ingredient of whisky production. Included within the inventory of InchDairnie's production are emissions associated with the production and harvesting of barley (e.g. fuel, fertilizer), and CO_2 sequestered as biogenic carbon within the barley.

In addition to these GHG emissions, the GHG Protocol for Product Life Cycle Accounting requires GHG emissions associated with land use *change* to be reviewed as part of the footprint method. Land use change refers to any changes to the land carbon stock associated with preparing the land for its current use. For example, if woodland was converted to cropland to produce barley, there would be a likely reduction in overall carbon stock. If this change happened within the past 20 years, it is recommended that the associated GHG emissions are apportioned over the following 20 years so that these GHG emissions are accounted for.

Within the present footprint it has not been possible to identify if land use change took place within the past 20 years on the agricultural land which produces the barley that is eventually purchased as malt by InchDairnie. Therefore, land use change is excluded from the footprint. This may be something that InchDairnie wants to investigate in future, or encourage industry to take a common approach to calculating.

Figure 1: Process Map



2.3 LCIA Methodology

The climate impact of InchDairnie's operations is calculated in the impact assessment chapter. The results are expressed in tonnes of CO_2e (CO_2 equivalent). This is an expression of the global warming potential (GWP), in terms of tonnes of CO_2, of the greenhouse gases emitted through processes allocated to InchDairnie's operations. Tonnes CO_2e is calculated by multiplying activity data (e.g. kWhs electricity) by the relevant emissions factor. Within this assessment, the emissions factors sourced are already expressed in tonnes CO_2e. Therefore, a conversion of non-CO_2 gases to CO_2e has not been undertaken as part of this assessment.

2.4 Allocation

For almost all process stages in this footprint the activity data collected directly relate only to the whisky produced by InchDairnie and therefore do not require an allocation process.

An exception is casks purchased for maturing of the whisky. The casks purchased have been previously used to store other alcoholic beverages (e.g. wines and bourbon), and therefore it is necessary to allocate only a proportion of the cask production emissions to their use by InchDairnie. The method used to allocate these emissions is as follows:

- Total expected lifetime of each cask type estimated by InchDairnie to be 50 years;
- Total years InchDairnie owns each cask estimated to be 20 years;
- Ratio of InchDairnie owned years to total cask lifetime is used to apportion the number of casks for which InchDairnie should take full ownership of production emissions
- This number of casks is multiplied by the emissions factor per cask produced to give a total apportioned emissions InchDairnie is responsible for; and
- This total emissions figure is divided by 20 (i.e. the number of years InchDairnie has ownership of the casks) to give an annual footprint.

This calculation is shown in the appendix.

This method means that the results presented in this report only contain an annualised proportion of allocated emissions from cask production. Future footprint studies may need to include multiple years of cask production emissions depending on the functional unit.

3.0 Inventory Analysis

Table 4 presents the activity data and emissions factors used to complete this footprint assessment. More detailed information, including the data sources and an assessment of where improvements could be made, is provided in the appendix.

Table 4: Inventory Data

Process	Process description	Activity data	Activity data unit	Emissions factor	Emissions factor unit
Barley Cultivation	CO_2 sequestered through growing barley.	6,394	Tonnes of barley	1.47	Tonnes CO_2 sequestered per tonne of barley
Malt Production	Conversion of barley to malt. A whisky ingredient.	4,995	Tonnes of malt	504	$KgCO_2e$/tonne malt
Yeast Production	Production of yeast. A whisky ingredient.	106,436	Litres	Cream yeast as dry matter: 2,019 Dry yeast as dry matter: 3,373	gCO_2e/kg
Water use	Delivery of mains water. A whisky ingredient.	41,302,000	Litres	344	$KgCO_2e$ /million litres
Cask Production	Casks are used to store and mature the whisky.	21,859	Casks	85	$KgCO_2e$/cask
Upstream Transportation	Transportation of yeast and casks to the distillery. (Transport of malt sits within the malt emissions factor).	See appendix.			

Process	Process description	Activity data	Activity data unit	Emissions factor	Emissions factor unit
Electricity	Electricity is used to light the distillery and power conveyer belts, pumps etc.	708,500	kWhs	Scope 2: 0.2556 Scope 3: 0.06038	KgCO_2e /kWh
Gas for heat	Gas is used for heating during the distilling process.	7,667,972	kWhs	Mains Natural Gas: Scope 1: 0.18385 Scope 3: 0.02391 Biogas: Scope 1: 0.00021 Scope 3: 0.02405	KgCO_2e /kWh
Fermentation	CO_2 is released through the conversion of sugars to alcohol.	1,882,398	Litres of alcohol	0.755	KgCO_2 per litre alcohol
Downstream Transportation	Transport of pot ale and draff for anaerobic digestion.	See appendix.			
Waste water	Processing of waste water.	22,588,779	Litres	708	KgCO_2e/million litres

4.0 Impact Assessment

GHG emissions are calculated by multiplying the InchDairnie activity data by the corresponding emissions factor. The activity data and emissions factors for each process are detailed in Section 3.0.

The results of the footprint are presented in three sections below. The rational of presenting each section is as follows:

1) **Grid-average and renewable electricity-based[2] results excluding biogenic emissions:** This presentation shows a per litre alcohol footprint including grid-average and renewable electricity scenarios, however excludes biogenic carbon.
2) **Grid-average and renewable electricity-based results including biogenic emissions:** This presentation shows a per litre alcohol footprint including grid-average and renewable electricity scenarios, and also includes biogenic carbon (carbon sequestered through barley cultivation, and CO_2 emitted through fermentation during the distilling process).
3) **The potential impact of consuming biogas rather than mains natural gas:** This presentation is intended to show the benefit of purchasing biogas rather than mains-delivered natural gas. It is a hypothetical scenario to inform InchDairnie's sustainability planning.

All graphs are presented on a Kg CO_2e/litre alcohol basis. Graphs showing the total organisational impact over the reporting period, presented as Tonnes CO_2e, are provided in the appendix.

4.1 Grid-average and renewable electricity-based results excluding biogenic sources

This section provides a breakdown of footprint results excluding biogenic sources (carbon sequestered during barley cultivation, and CO_2 released during fermentation), and shows the difference between using a grid-average electricity emissions factor (i.e. the UK grid average electricity emissions intensity) and taking into consideration InchDairnie's renewable electricity tariff (and therefore assuming electricity associated GHG emissions to be zero).

Figure 2 summarises these footprint results across each life cycle stage. The processes within each life cycle stage are described previously in Table 3. Figure 3 beaks the footprint down into individual processes. Table 5 provides a numerical summary of the results.

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[2] There are two ways of calculating electricity carbon emissions. The 'location based' method uses the average grid emissions factor. The 'market based' method uses the specific emissions factor for the electricity tariff purchased.

Figure 2: KG CO2e per Litre Alcohol by Life-Cycle Stage

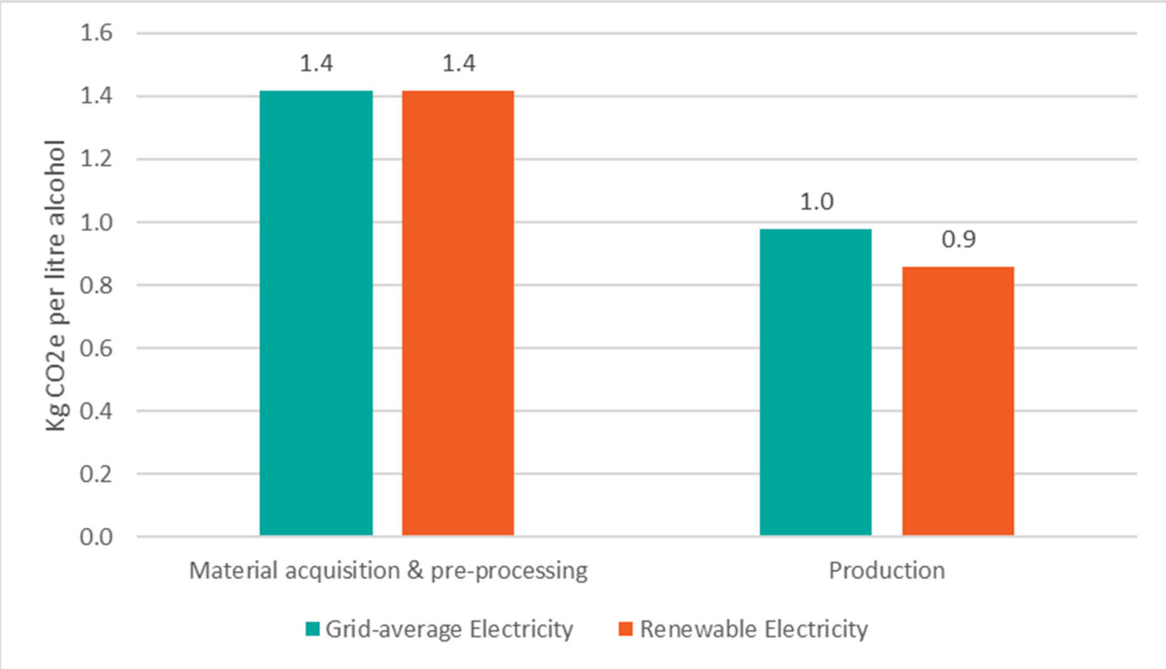


Figure 3: Breakdown of Emission Sources

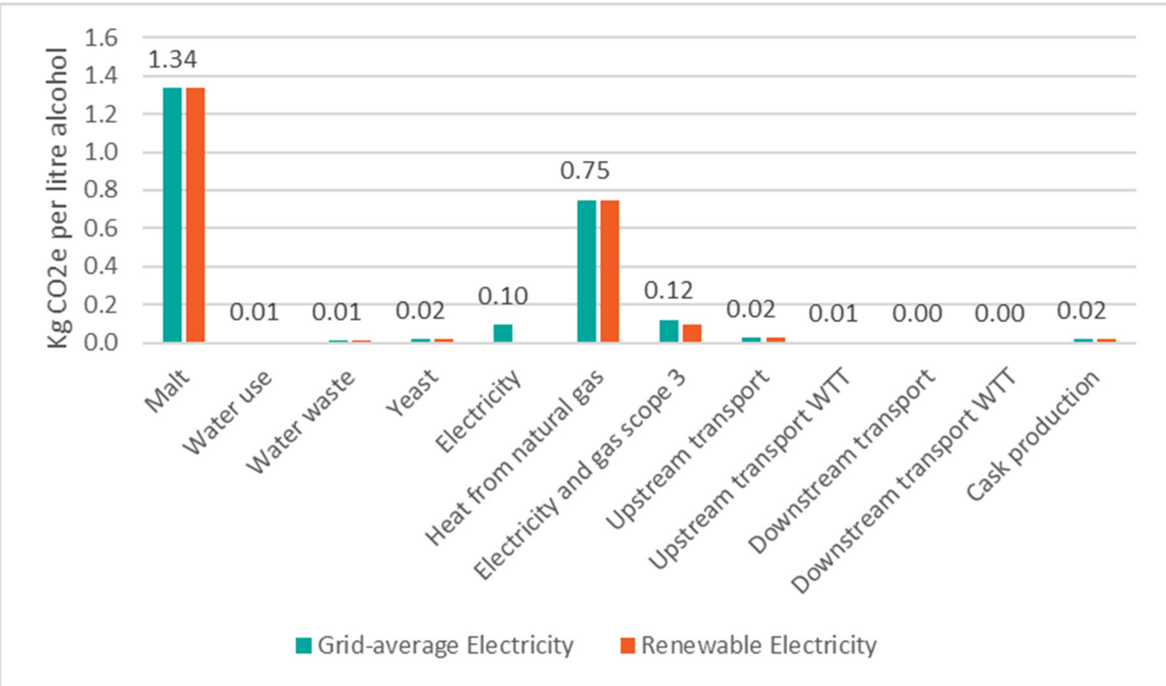


Table 5: Numerical Breakdown of Results

	Grid-average electricity			Renewable electricity		
Emissions source	**Tonnes CO_2e (total production)**	**Kg CO_2e/litre alcohol**	**% 2019 footprint**	**Tonnes CO_2e (total production)**	**Kg CO_2e/litre alcohol**	**% 2019 footprint**
Malt	2,518	1.34	55.9%	2,518	1.34	58.8%
Water use	14	0.01	0.3%	14	0.01	0.3%
Water waste	16	0.01	0.4%	16	0.01	0.4%
Yeast	40	0.02	0.9%	40	0.02	0.9%
Electricity	181	0.10	4.0%	0	0.00	0.0%
Heat from natural gas	1,410	0.75	31.3%	1,410	0.75	32.9%
Electricity and gas scope 3	226	0.12	5.0%	183	0.10	4.3%
Upstream transport	47	0.02	1.0%	47	0.02	1.1%
Upstream transport WTT	10	0.01	0.2%	10	0.01	0.2%
Downstream transport	4	0.00	0.1%	4	0.00	0.1%
Downstream transport WTT	1	0.00	0.0%	1	0.00	0.0%
Cask production	37	0.02	0.8%	37	0.02	0.9%
Total	**4,504**	**2.39**	**100.0%**	**4,280**	**2.27**	**100.0%**

4.2 Grid-average and renewable electricity-based results including biogenic sources

This section provides a breakdown of footprint results including biogenic sources (carbon sequestered during barley cultivation, and CO_2 released during fermentation), and shows the difference between using a grid-average electricity emissions factor (i.e. the UK grid average electricity emissions intensity) and taking into consideration InchDairnie's renewable electricity tariff (and therefore assuming electricity associated GHG emissions to be zero).

Figure 4 summarises these results across each life cycle stage. Figure 5 beaks the footprint down into individual processes. The processes within each life cycle stage are described previously in Table 3. Table 6 provides a numerical summary of the results.

It is important to state that these results should not be interpreted as showing that whisky production delivers a net sequestration of carbon. Carbon sequestered through the growing of barley will gradually be released throughout the product's lifespan, negating the initial sequestration. Within the scope of this footprint only CO_2 emissions released through fermentation are shown. However, once extended to include additional end-of-life processes, further GHG emissions will be released, through processes such as the decomposition of pot ale and draff through anaerobic digestion. Therefore, over the lifetime of the product, biogenic carbon sources and sinks are likely to have a net zero impact.

Figure 4: KG CO2e per Litre Alcohol by Life-Cycle Stage

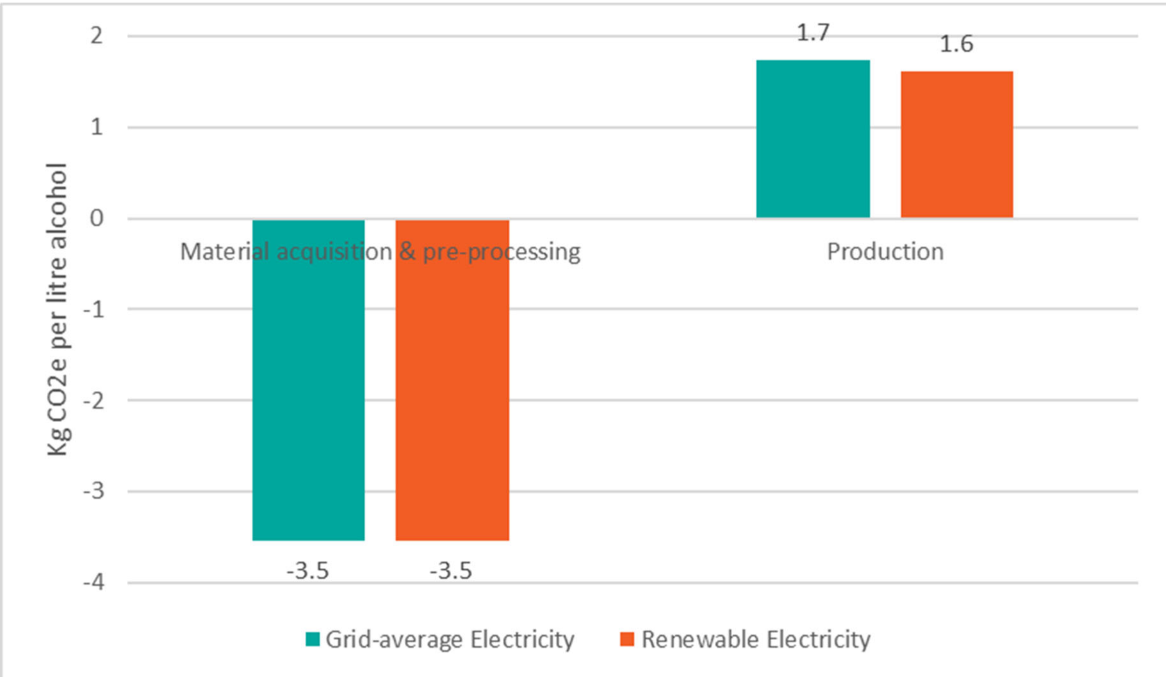


Figure 5: Breakdown of Emission Sources and Sinks

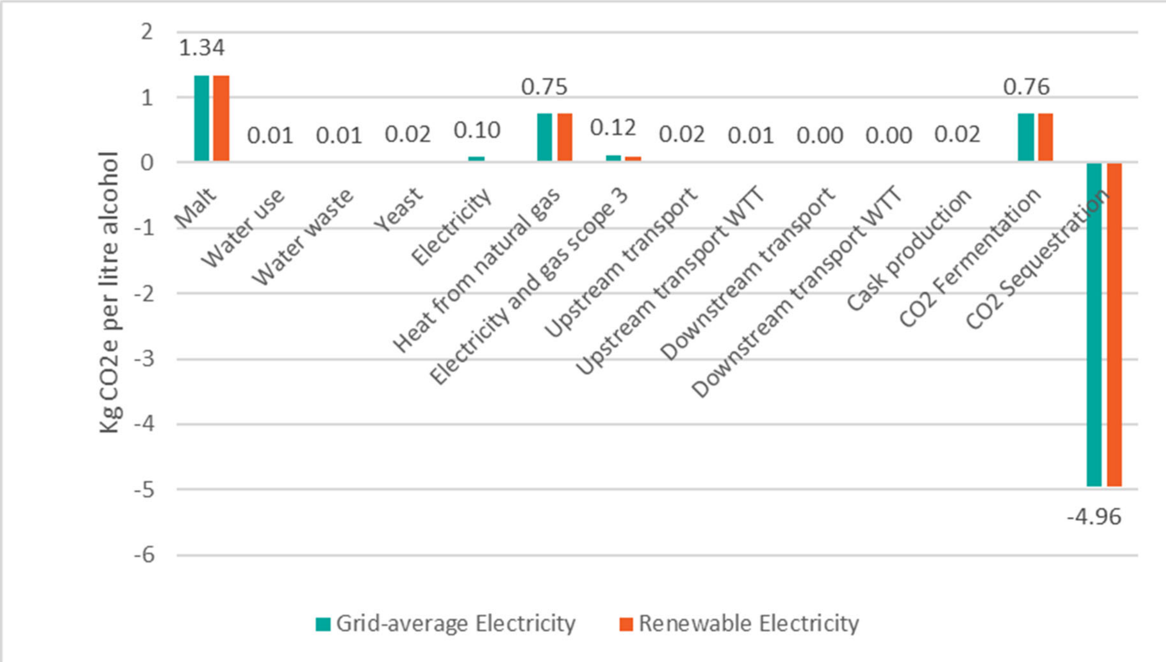


Table 6: Numerical Breakdown of Results

Emissions source	Grid-average electricity			Renewable electricity		
	Tonnes CO_2e (total production)	Kg CO_2e/litre alcohol	% of 2019 footprint	Tonnes CO_2e (total production)	Kg CO_2e/litre alcohol	% of 2019 footprint
Malt	2,518	1.34	-73.9%	2,518	1.34	-69.4%
Water use	14	0.01	-0.4%	14	0.01	-0.4%
Water waste	16	0.01	-0.5%	16	0.01	-0.4%
Yeast	40	0.02	-1.2%	40	0.02	-1.1%
Electricity	181	0.10	-5.3%	0	0.00	0.0%
Heat from natural gas	1,410	0.75	-41.4%	1,410	0.75	-38.8%
Electricity and gas scope 3	226	0.12	-6.6%	183	0.10	-5.1%
Upstream transport	47	0.02	-1.4%	47	0.02	-1.3%
Upstream transport WTT	10	0.01	-0.3%	10	0.01	-0.3%
Downstream transport	4	0.00	-0.1%	4	0.00	-0.1%
Downstream transport WTT	1	0.00	0.0%	1	0.00	0.0%
Cask production	37	0.02	-1.1%	37	0.02	-1.0%
CO_2 Fermentation	1,421	0.76	-41.7%	1,421	0.76	-39.2%

Emissions source	Grid-average electricity			Renewable electricity		
	Tonnes CO_2e (total production)	Kg CO_2e/litre alcohol	% of 2019 footprint	Tonnes CO_2e (total production)	Kg CO_2e/litre alcohol	% of 2019 footprint
CO_2 Sequestration	-9,330	-4.96	274.0%	-9,330	-4.96	257.1%
Total	**-3,405**	**-1.81**	**100.0%**	**-3,629**	**-1.93**	**100.0%**

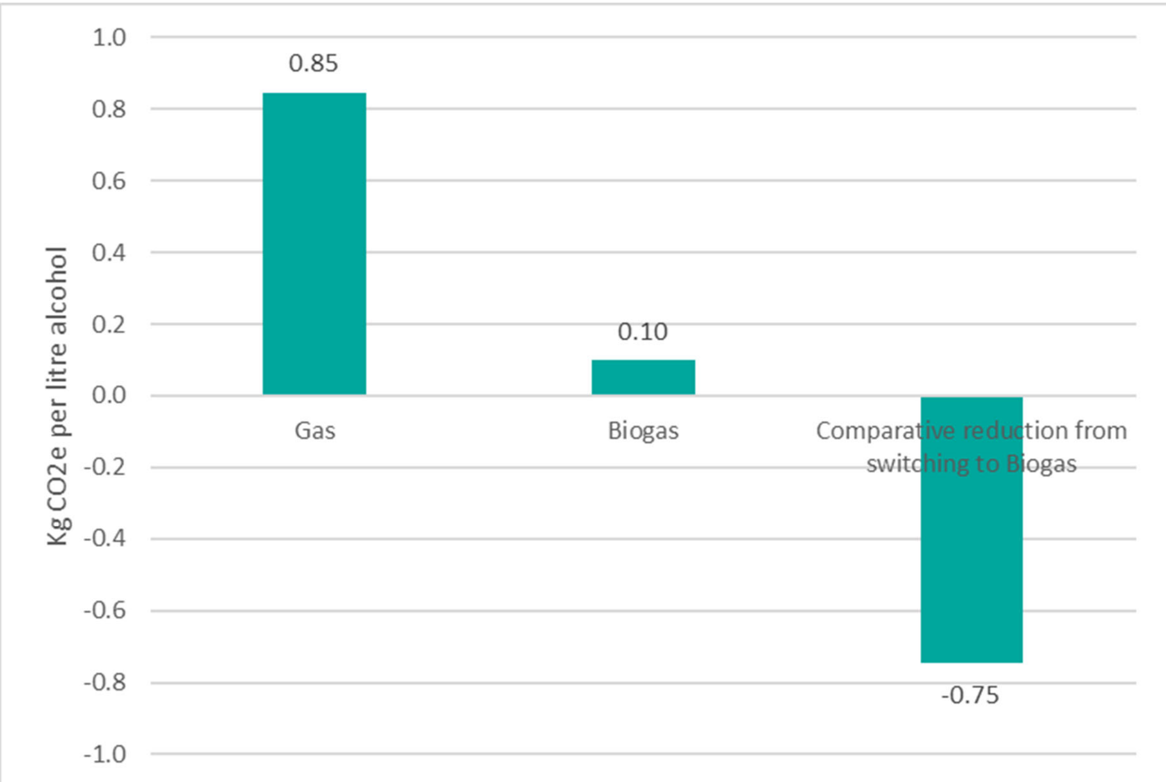
4.3 Potential Impact of Consuming Biogas Rather than Mains Natural Gas

InchDairnie presently uses mains delivered natural gas. It may be possible in future for InchDairnie to be directly connected to a nearby anaerobic digestion facility. This is also the facility where InchDairnie's pot ale and draff is sent for conversion to biogas, and therefore presents the opportunity for a more circular distilling process. InchDairnie has requested an assessment of the impact of consuming biogas from this local anaerobic digester to inform its business planning.

The UK Government Greenhouse Gas Conversion Factors for Company Reporting includes separate emission factors for biogas and mains gas. The emission factor for biogas is very small. This is because the carbon dioxide released during burning of the produced methane forms part of the 'short term' carbon cycle, and was previously absorbed during the growth of the biological material that was input into the AD process. Other GHGs (CH_4 and N_2O) that are emitted are still accounted for, as these do not form part the carbon cycle. Well-to-tank emissions associated with the processing and transport of fuels are also included within the biogas footprint.

The net benefit of switching to biogas is a total saving of approximately 1,400 tonnes CO_2e per year, or ~0.75 Kg CO_2e per litre alcohol, approximately 30% of annual emissions (when excluding carbon sequestration and CO_2 released during fermentation). Figure 6 shows the impact of switching to biogas on a per litre alcohol basis.

Figure 6: Impact of Switching from Mains Gas to Biogas



If InchDairnie sources gas directly from this AD plant in the future (i.e. through a direct connection), it seems logical that this approach to carbon footprinting could be pursued. However, if InchDairnie enters into a contractual commitment to purchase the biogas, rather than through a direct connection (much like using Renewable Energy Guarantees of Origin (REGOs)) it should be noted that a common system for claiming the emission reductions is yet to be established. A system may be developed that is similar to the market-based vs location-based system for electricity reporting. However, it is not yet entirely clear what recommended practice will be for accounting for the associated emission reductions within Net Zero targets.

5.0 Interpretation

5.1 Results and Opportunities for Emission Reductions

With the exception of biogenic emission sources, the largest contributor to InchDairnie's emissions is the production of malt. This represents 56% of GHG emissions under the electricity grid average-based footprint, and 59% under the renewable electricity-based footprint.

The malt footprint provided by Muntons demonstrates that approximately half of the emissions of producing malt are associated with agricultural production (e.g. fuel and fertilizer use), and half are associated with electricity and gas used to convert the harvested grain into malt. Reducing GHG emissions from farmed crops is challenging, requiring long-term planning and cooperation with agricultural suppliers. For this reason, in the short term at least, the malt footprint may not the be the most realistic area of GHG emissions in which InchDairnie is able to make GHG emission savings. We would recommend InchDairnie continues a dialogue with Muntons to assess whether lower carbon malt supplies may become available in the future, understanding that Muntons are already forward thinking with regard to their carbon footprint and the scope for further reduction may be limited.

The second and third most prominent GHG emission sources are gas and electricity consumption at InchDairnie's facilities: gas makes up 31% under the grid-average-based footprint and 33% under the renewable electricity-based footprint; electricity comprises 4% of the grid-average-based footprint and 0% of the renewable electricity-based footprint.

InchDairnie has much greater control over these GHG emission sources and it is more realistic to make reductions in these areas. The company has purchased 100% renewable electricity, meaning under the 'market based'[3] system of carbon footprint reporting, InchDairnie reports an electricity footprint of zero tonnes, reducing the footprint by 224 tonnes CO_2e (this figure includes well-to-tank and transmission and distribution emissions from electricity). Given that electricity will continue to be used in the warehouse during maturation, this switch will also result in further cumulative reductions in emissions over time. Whilst a positive result, we would encourage InchDairnie to continue to investigate options for onsite renewable generation, or direct power purchase agreements with local renewables operators. These solutions are generally recognised to deliver greater 'additionality' and encourage new renewable electricity generation capacity, as opposed to using the REGO system.

The assessed impact of purchasing biogas has shown this could reduce InchDairnie's annual footprint by approximately 30% per year. This provides encouragement to investigate a direct link between the local anaerobic digester and the distillery. It should be borne in mind that if a direct link with the anaerobic digester is not possible, emissions reporting systems are currently ambiguous about how green gas purchased through 'certificates' or

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[3] There are two ways of calculating electricity carbon emissions. The 'location based' method uses the average grid emissions factor. The 'market based' method uses the specific emissions factor for the electricity tariff purchased.

other contractual mechanisms should be claimed within Net Zero targets. In addition to switching gas source, identifying opportunities to improve the efficiency of heating within the distillery will help reduce gas consumption and associated emissions.

Scope 3 energy emissions represent 5% of the grid-average-based footprint and 4% of renewable electricity-based footprint. These include well-to-tank emissions and transmission and distribution emissions associated electricity consumption, and well-to-tank emissions associated with gas consumption. In the renewable electricity scenario, the electricity component of these emissions is negated. The well-to-tank emissions associated with gas will reduce if overall gas consumption reduces, but under carbon accounting guidelines, WTT is still included in the biogas assessment. Should the direct link with the anaerobic digester progress, undertaking a detailed, site-specific review of the anaerobic digester may mean a case can be made to reduce the calculated impact of these WTT GHG emissions.

The remaining non-biogenic footprint components constitute only 4% of overall emissions for both renewable and grid-average-based electricity footprints. Activities such as ensuring delivery lorries are fully loaded are already in place, and processes such as water use or cask manufacture are fixed elements of scope 3 impact. That said, discussions with suppliers may yield opportunities to make additional progress in reducing these GHG emissions in future, such shifting to electric or hydrogen logistics vehicles (recognising, of course, that these options are very limited at present). In addition, it will be useful to undertake a further footprinting exercise once the single malt whisky is bottled, which will provide an understanding of the relative significance of packaging emissions and comparisons to be made with other finished whisky products, as well as enabling a full cradle-grave footprint scope. Preferably, the relative embodied carbon and end-of-life impacts will be addressed during the packaging selection processes, so that decisions can be made to minimise GHG emissions and other environmental impacts from the outset.

The assessment of biogenic carbon sources and sinks within the boundary of this footprint shows substantial carbon sequestration through barley cultivation. Some of this carbon is emitted through fermentation during the distilling process. This should not be seen to suggest that whisky production is a net sequester of carbon, as over the entire lifetime of the product (i.e. beyond the scope of this assessment) all the sequestered carbon is likely to be emitted. The inclusion of biogenic carbon within this assessment is therefore only relevant as an academic carbon accounting exercise and does not undermine the case for reducing emissions from non-biogenic sources.

5.2 Calculation Uncertainties and Opportunities for Improvement

A detailed breakdown of the data sources included within the assessment is provided in the appendix. Overall, InchDairnie was able to provide good access to data. The footprint has been calculated using primary activity data where possible, and in most instances has applied widely used emission factors, or emission factors provided by InchDairnie's suppliers. The areas where the footprint would benefit from greater research in order to reduce uncertainty are as follows:

- **Emissions released during fermentation**: Only one literature source has been used in this assessment. Further investigation of this process – in the literature, or through discussion with industry - would help refine this calculation and improve confidence in the results.

- **Emissions associated with cask production:** One literature source has been used within this study. A wider assessment of sources and their relative applicability to the casks used by InchDairnie would improve confidence in this calculation.
- **Emissions associated with yeast production:** One literature source has been used within this study. To use this source, a litre to kg conversion for yeast cream and dry yeast has been applied. A review of wider literature sources and possible consultation with industry would help refine this conversion, and also enable comparison of the emission factor source with other studies and data.
- **Emissions associated with malt production:** This element of the footprint has utilised a supplier carbon factor. Third party review of this source and/or comparison with other studies would enable a view of its accuracy and completeness to be formed.
- **Carbon sequestered through barley cultivation:** This calculation has relied upon a literature source for the carbon content of cereals and the IPCC conversion method from biogenic carbon to CO_2. This method may overlook finer details, such as the role of soil carbon and land use change. An industry approach to accounting for these impacts would improve consistency and confidence in the method.

Appendix

A.1.0 Further Information: Activity Data and Emission Factors

This appendix provides further background information on the activity data and emissions factors used within this assessment. This information is presented in two sub-chapters: material acquisition and pre-processing, and production. Within each sub-chapter a section is dedicated to each process presented in Figure 1. A table is presented within each process that includes:

- **Description:** A description of the role this activity plays in InchDairnie's operations
- **Activity data:** for example, total kWhs electricity consumed
- **Activity data source:** for example, where the electricity consumption data was accessed from
- **Opportunities to improve the activity data source**
- **Emissions factor:** this is presented in tonnes CO_2e per unit (e.g. tonnes CO_2e per kWh), or tonnes CO_2 (if CO_2 is the only relevant GHG)
- **Emissions factor source:** for example, the database or literature source
- **Opportunities to improve the emissions factor source**

A.1.1 Material Acquisition and Pre-processing

Barley Cultivation (biogenic sequestration)

Description	Barley is converted to malt through the malting process. Malt is then used as a whisky ingredient.
Activity Data	6,394 tonnes of barley were used to produce the malt used by InchDairnie during the reporting period. This is derived by multiplying the annual tonnes of malt purchased (4,995 tonnes), by 1.28, which is the ratio of barley required to produce 1 tonne of malt.
Activity Data Source	Tonnes of malt data was sourced from InchDairnie procurement records. 1.28 multiplication factor was sourced from InchDairnie's malt supplier.
Opportunities to Improve Activity Data Source	Third party verification of the 1.28 multiplication factor would provide additional assurance of this value. Triangulation with additional literature sources would also test validity.
Emissions Factor (in this case, biogenic sequestration)	1.47 tonnes CO_2 sequestered per tonne of barley. The following method was applied to calculate this factor. Carbon content of barley found to be ~40% for barley grown at UK latitudes (InchDairnie's barley is sourced from Fife and Yorkshire). This carbon content is converted to sequestered CO_2 using IPCC

	method of multiplying the carbon stock by 44/12 (the ratio of molecular weights). This is presented in the following calculation: • 6,394 tonnes barley * 0.4 = 2,558 tonnes carbon • 2,558 tonnes carbon * (44/12) = 9,379 tonnes CO_2 9,379 tonnes CO_2 / 6,394 tonnes barley = 1.47 tonnes CO_2 sequestered per tonne of barley
Emissions Factor Source	Carbon content of barley sourced from Ma et al 2018.[4] Emission factor derived as per calculation above.
Opportunities to Improve Emissions Factor Source	Review of further academic sources to establish carbon content of barley would improve certainty. Soil carbon content has not been addressed in this review and may influence results. Direct carbon content analysis of the barley in InchDairnie's supply chain would provide the most accurate results.

Malt Production

Description	Malt is a whisky ingredient, produced via conversion of barley through a malting process.
Activity Data	4,995 tonnes of malt were purchased during the reporting period.
Activity Data Source	InchDairnie procurement records.
Opportunities to Improve Activity Data Source	NA.
Emissions Factor	504 kg CO_2e/tonne malt
Emissions Factor Source	Carbon footprint of malt production provided by Muntons, InchDairnie's supplier.
Opportunities to Improve Emissions Factor Source	Muntons' carbon footprint for growing and malting barley used Muntons' own model and utilised the ECOINVENT database. A detailed evaluation of this data source was not undertaken as part of this footprint and would be recommended to provide a third-party review of its accuracy and comprehensiveness.

[4] Ma et al., Variations and determinants of carbon content in plants: a global synthesis (2018) Biogeosciences, 15, 693–702, 2018 https://doi.org/10.5194/bg-15-693-2018

Yeast Production

Description	Yeast is a whisky ingredient.
Activity Data	106,436 litres of yeast were used during the reporting period. Of this, InchDairnie reported 90% was cream yeast, 10% was dry yeast.
Activity Data Source	InchDairnie procurement records.
Opportunities to Improve Activity Data Source	Data was provided as total litres. It was necessary to apply two conversions to this data: 1) Convert the litres of cream and dry yeast to dry matter. This conversion used dry matter content %ages from the emission factor source (see below) 2) To convert litres to Kgs, using a conversion of 0.58kgs per litre dry yeast.[5] There is some uncertainty about the litre to kg conversion as data sources were sparse on this subject. Discussion with yeast providers would enable these assumptions to be tested and reviewed.
Emissions Factor	Yeast cream as dry matter: 2,019 g CO_2e/kg Yeast dry as dry matter: 3,373 g CO_2e/kg
Emissions Factor Source	Confederation of EU Yeast Producers/PwC [6]
Opportunities to Improve Emissions Factor Source	An evaluation of this data source was not undertaken as part of this footprint. A third-party review of this data source, as well as comparison with other literature sources, would enable the accuracy of the factor to be tested.

[5] Traditional Oven (2019) Brewer's Yeast Conversion, accessed 17/11/20 https://www.traditionaloven.com/culinary-arts/baking/brewers-yeast/convert-liter-l-of-brewers-yeast-to-kilogram-kg-brewers-yeast.html

[6] Confederation of European Yeast Producers/PwC *Yeast Carbon Footprint*, http://www.cofalec.com/sustainability/yeast-carbon-footprint/

Water Consumption

Description	Water is a whisky ingredient.
Activity Data	41,302,000 litres of water (100% mains supplied) were consumed during the reporting period.
Activity Data Source	InchDairnie procurement records.
Opportunities to Improve Activity Data Source	NA.
Emissions Factor	344 $KgCO_2e$/million litres
Emissions Factor Source	UK Government GHG Conversion Factors[7]
Opportunities to Improve Emissions Factor Source	This emissions factor database is widely used for UK company reporting. An emissions factor from the regional water management company may be available and would provide a more geographically specific result for InchDairnie.

Cask Production

Description	Casks are used to store and mature the whisky.
Activity Data	21,859 casks where purchased during the reporting period.
Activity Data Source	InchDairnie procurement records.
Opportunities to Improve Activity Data Source	NA.
Emissions Factor	85 kg CO_2e/cask.
Emissions Factor Source	Flor, F.J., et al, 2017 [8]
Allocation Calculation	• Percentage of cask lifetime InchDairnie is responsible for: 20 years / 50 years = **40%** • Carbon Factor for cask manufacture = 85 kg CO_2e/cask

[7] UK Government (2019) Greenhouse gas reporting: conversion factors, https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting

[8] Flor, F.J., et al, (2017). Environmental impact of oak barrels production in Qualified Designation of Origin of Rioja. *Journal of Cleaner Production,* 167, 208-217.

	- Kg CO_2e of cask production InchDairnie is responsible for: Number of casks (21,859) * 85 kg CO_2e/cask * 40% = **743,206** - To annualise, divide by 20: 743,206/20 = **37,160** - Converting KG CO_2e to Tonnes CO_2e per year: 37,160/1000 = **37**
Opportunities to Improve Emissions Factor Source	Only one source was used to inform calculations of emissions associated with cask production. It is recommended future assessments seek additional sources to improve certainty of this emissions factor.

Upstream Transportation

Description	Transportation of casks and yeast to the distillery. Transport of malt was included within the malt emissions factor.
Activity Data	'Tonne.kms' travelled by various freight modes. (1 tonne.km means 1 tonne has travelled 1 km).
Activity Data Source	Calculated using the weight of materials transported to the distillery, the freight modes, and distances travelled. For activity data pertaining to yeast transport see Table 7. For activity data pertaining to cask transportation see Table 8.
Opportunities to Improve Activity Data Source	Google maps and shipping navigation websites were used to estimate transport distances. Using this method is likely to lead to some variation to the true distances transported, but the impact on the footprint is deemed to be negligible.
Emissions Factor	See appendix A.1.3 for transport emissions factors.
Emissions Factor Source	UK Government GHG Conversion Factors
Opportunities to Improve Emissions Factor Source	The freight modes used were selected using Eunomia's best judgement. Future analysis may benefit from studying the freight modes in more depth to provide a further check that the most appropriate modes have been selected.

Table 7: Yeast transportation activity data

Litres	Converted to tonnes	Distance transported	Tonne.kms
106,436	106,436 (no data could be found to covert litres of cream yeast to kgs. Therefore it is assumed 1 litre yeast cream weights 1kg)	496 kms	52,792

Table 8: Cask transportation activity data

Cask type	Number of casks	Weight per cask (tonnes)	Road distance transported (kms)	Rail distance transported (kms)	Shipped distance transported (kms)
Refills	17,048	0.06	48	0	0
Rioja	700	0.075	277	0	1453
Tuscan	280	0.075	75	761	2,004
Ex bourbon	2,651	0.06	1,108	0	6,399
New US	410	0.06	1,108	0	6,399
Port	140	0.075	74	0	2,233
Spanish fortified	630	0.075	304	0	3,040

A.1.2 Production

Distilling – Electricity

Description	Electricity used in the distillery.
Activity Data	708,500 kWhs electricity consumed during reporting period.
Activity Data Source	InchDairnie procurement records.
Opportunities to Improve Activity Data Source	NA
Emissions Factor	Scope 2: 0.2556 kg CO_2e/kWh Scope 3: 0.06038 kg CO_2e/kWh (includes well-to-tank (generation and transmission and distribution), and transmission and distribution)
Emissions Factor Source	UK Government GHG Conversion Factors
Opportunities to Improve Emissions Factor Source	NA

Distilling – Natural Gas

Description	Natural Gas used in the distillery.
Activity Data	7,667,972 kWhs gas consumed during reporting period.
Activity Data Source	InchDairnie procurement records.
Opportunities to Improve Activity Data Source	NA
Emissions Factor	Mains Natural Gas: Scope 1: 0.18385 kg CO_2e/kWh Scope 3: 0.02391 kg CO_2e/kWh (well-to-tank) Biogas from anaerobic digestion: Scope 1: 0.00021 kg CO_2e/kWh Scope 3: 0.02405 kg CO_2e/kWh (well-to-tank)
Emissions Factor Source	UK Government GHG Conversion Factors
Opportunities to Improve Emissions Factor Source	NA

Distilling – Fermentation

Description	The fermentation process converts fermentable sugars into alcohol and CO_2.
Activity Data	Total litres whisky produced during reporting period: 2,964,406. Alcohol content of whisky at beginning of maturation process: 63.5% Total litres alcohol produced during reporting period: 1,882,398
Activity Data Source	InchDairnie production records and alcohol testing procedure.
Opportunities to Improve Activity Data Source	NA
Emissions Factor (in this instance, biogenic emissions)	The fermentation process produces 0.755 kg CO_2 per litre pure alcohol.
Emissions Factor Source	Scottish Carbon Capture and Storage Report.[9] In this source, the ratio of CO_2 to alcohol produced was estimated from first principles by assuming fermentation of one molecule of glucose gives rise to two molecules of alcohol (ethanol) and two molecules of CO_2, that is, a 1:1 molar ratio. Adjusting this for molecular weights of ethanol (46) and CO_2 (44), and for the density of ethanol (0.789 kg per litre) leads to a figure of 0.755 kg CO_2 being produced for every litre of pure alcohol.
Opportunities to Improve Emissions Factor Source	Standard industry practice for reporting GHG emissions from fermentation could not be identified. Only one source was identified to inform our calculation. Future work would benefit from further investigation of emissions produced during fermentation, either within the literature, or broader discussion in the industry.

[9] Scottish Carbon Capture and Storage (2018) Negative Emission Technology in Scotland: carbon capture and storage for biogenic CO_2 emissions http://www.sccs.org.uk/images/expertise/reports/working-papers/WP_SCCS_2018_08_Negative_Emission_Technology_in_Scotland.pdf

Waste Water Processing

Description	Wastewater treatment
Activity Data	22,588,779 litres of wastewater Calculated by multiplying the total litres of alcohol produced during the period 2019 by 12: 1,882,398 litres * 12 = 22,588,779 litres
Activity Data Source	InchDairnie reporting.
Opportunities to Improve Activity Data Source	Physical measurement of waste water, rather than estimation method (i.e. using multiplying by 12) would be recommended.
Emissions Factor	708 kg CO_2e/million litres
Emissions Factor Source	UK Government GHG Conversion Factors for water treatment.
Opportunities to Improve Emissions Factor Source	This emissions database is widely used for UK company reporting. An emissions factor from the regional water management company may be available and would provide a more geographically specific result for InchDairnie.

Transport of Waste Outputs

Description	Transport of pot ale and draff to the anaerobic digester.
Activity Data	Tonne.kms of draff and pot ale sent for anaerobic digestion. 15,677 tonnes pot ale transported an average distance of 3.28 km 4,995 tonnes draff transported an average distance of 3.28 km
Activity Data Source	InchDairnie reporting.
Opportunities to Improve Activity Data Source	Draff figure is estimated based on starting tonnage of malt. The accuracy of this calculation could be improved by directly measuring the weight of draff sent for animal feed.

Emissions Factor	Road: (All arctics, 100% laden): 0.05824 Kg CO_2e/tonne.km
Emissions Factor Source	UK Government GHG Conversion Factors
Opportunities to Improve Emissions Factor Source	NA.

A.1.3 Transport Emission Factors

Direct fuel consumption

Transport type	Emission Factor	Unit	Source
All arctics (100% laden)	0.05824	Kg CO_2e/tonne.km	UK Government GHG Conversion Factors for Company Reporting, 2019
All arctics (average laden)	0.08306	Kg CO_2e/tonne.km	UK Government GHG Conversion Factors for Company Reporting, 2019
Rail freight	0.03333	Kg CO_2e/tonne.km	UK Government GHG Conversion Factors for Company Reporting, 2019
Cargo ship (general cargo, average dead-weight tonnage)	0.01323	Kg CO_2e/tonne.km	UK Government GHG Conversion Factors for Company Reporting, 2019

Well-to-tank

Transport type	Emission Factor	Unit	Source
All arctics (100% laden)	0.01434	Kg CO_2e/tonne.km	UK Government GHG Conversion Factors for Company Reporting, 2019
All arctics (average laden)	0.01967	Kg CO_2e/tonne.km	UK Government GHG Conversion Factors for Company Reporting, 2019
Rail freight	0.00783	Kg CO_2e/tonne.km	UK Government GHG Conversion Factors for

Transport type	Emission Factor	Unit	Source
			Company Reporting, 2019
Cargo ship (general cargo, average dead-weight tonnage)	0.00256	Kg CO_2e/tonne.km	UK Government GHG Conversion Factors for Company Reporting, 2019

A.2.0 Total CO_2e Results

The total 2019 annual footprint results for all whisky production at InchDairnie's site are presented in charts below. Results are given as Tonnes CO_2e/year.

A.2.1 Grid-average and renewable electricity-based results excluding biogenic sources

Figure 7: Emissions by Life-Cycle Stage

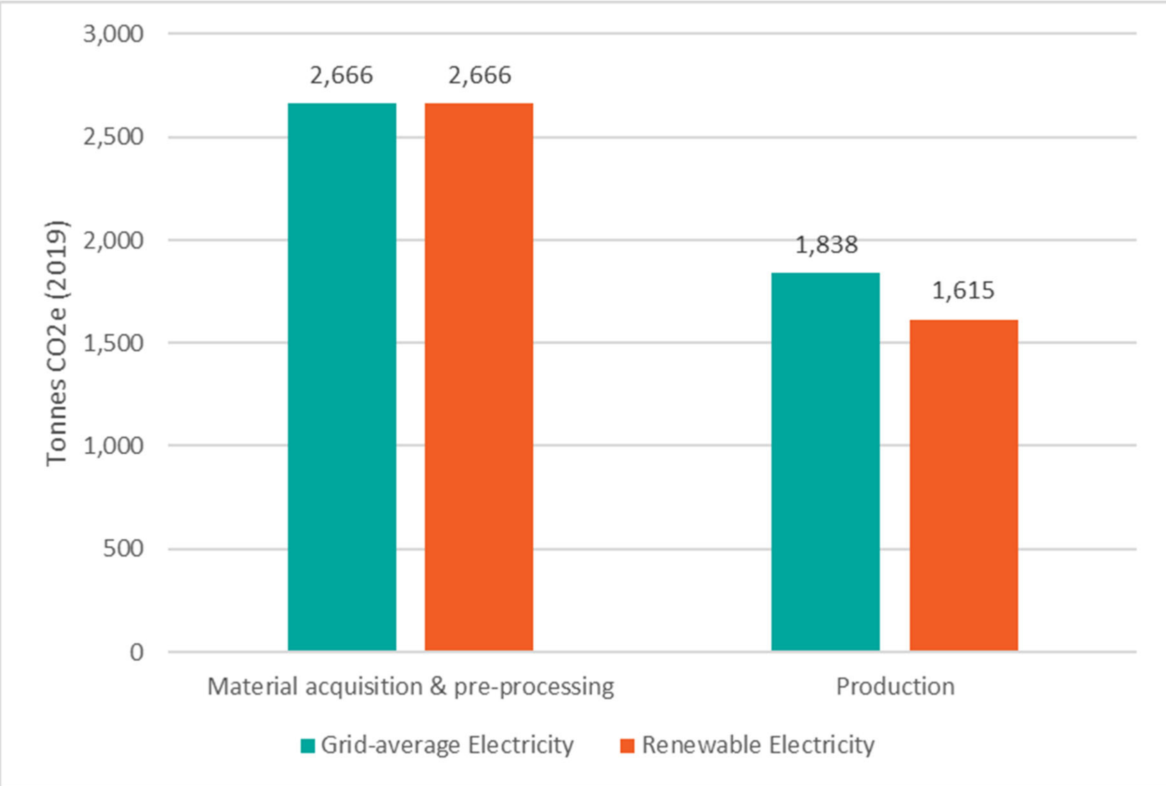
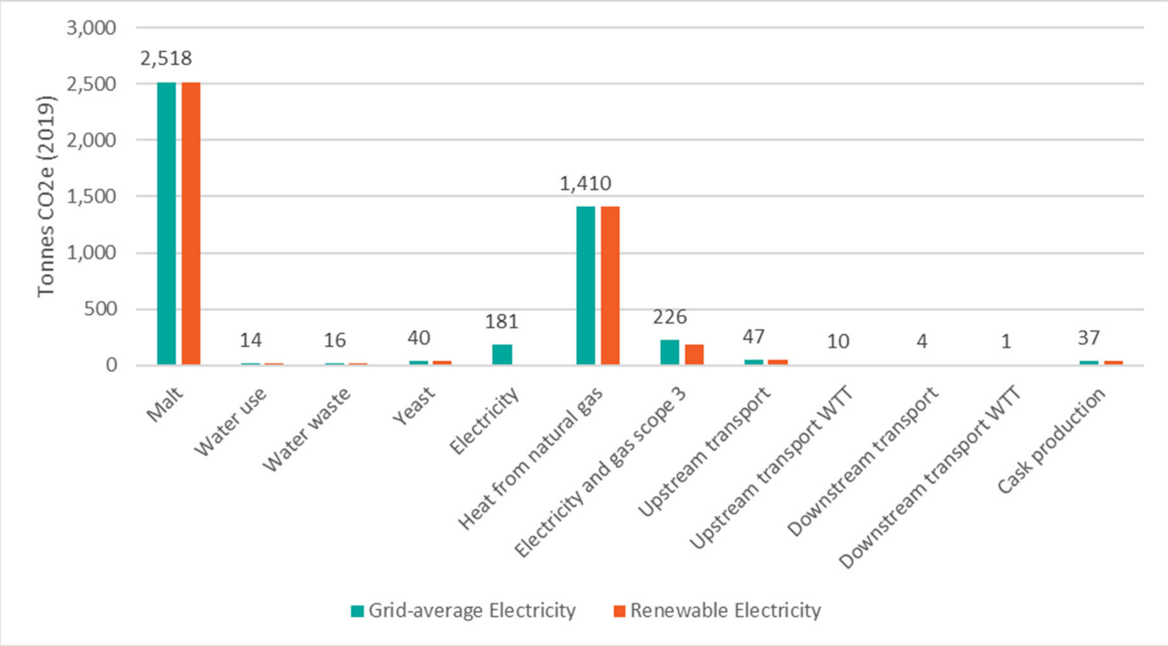


Figure 8: Breakdown of Emission Sources



A.2.2 Grid-average and renewable electricity-based results including biogenic sources

Figure 9: Emissions by Life-Cycle Stage

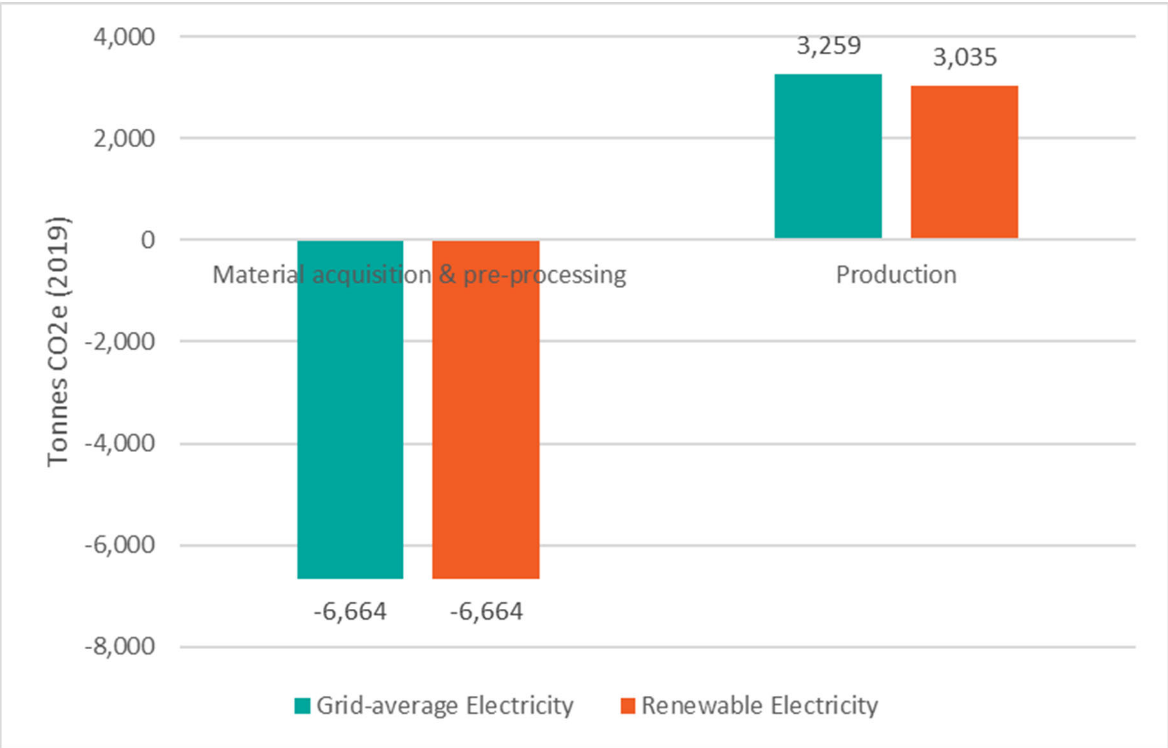
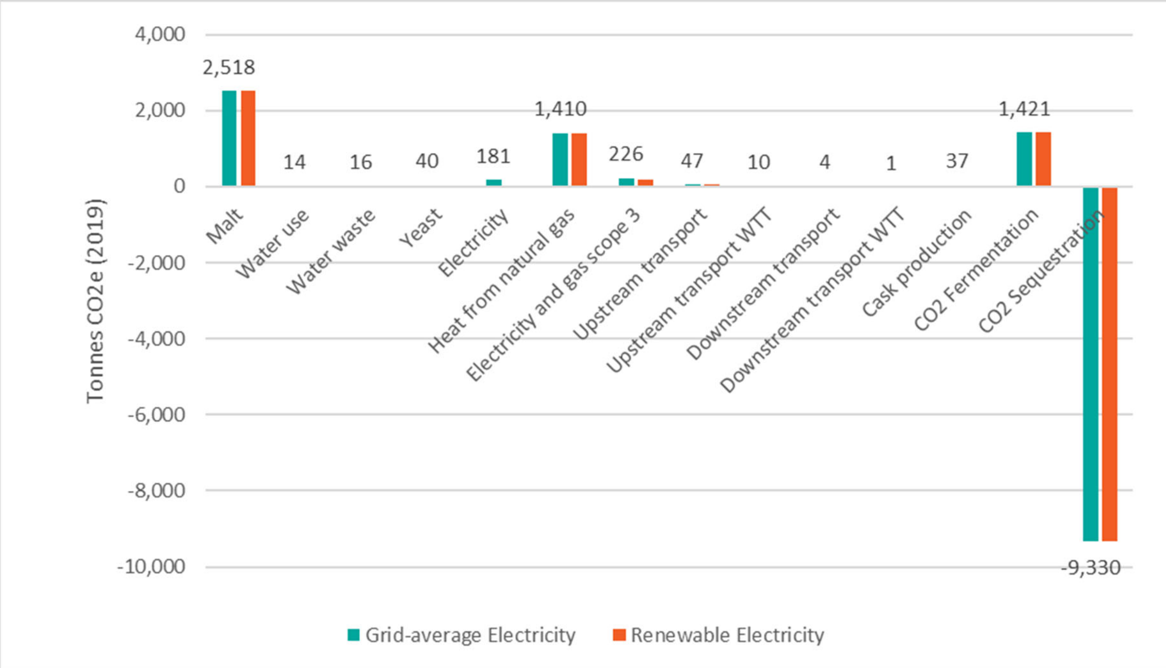


Figure 10: Breakdown of Emission Sources and Sinks



A.2.3 Potential Impact of Consuming Biogas Rather than Mains Natural Gas

Figure 11: Impact of Switching from Mains Gas to Biogas